VOL. 2 NO. 11

NOVEMBER 1961

RADIO & ELECTRONIC COMPONENTS

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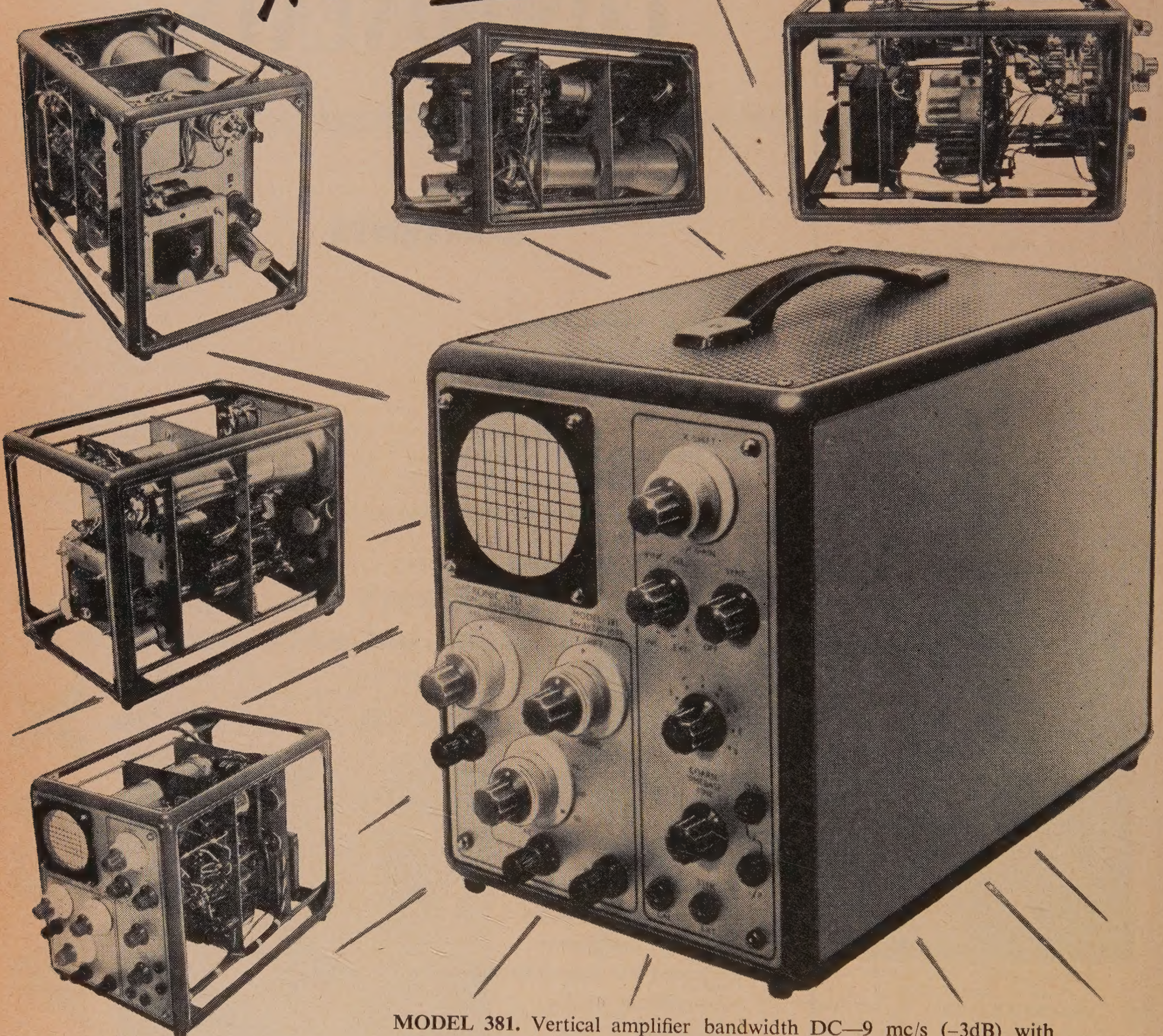

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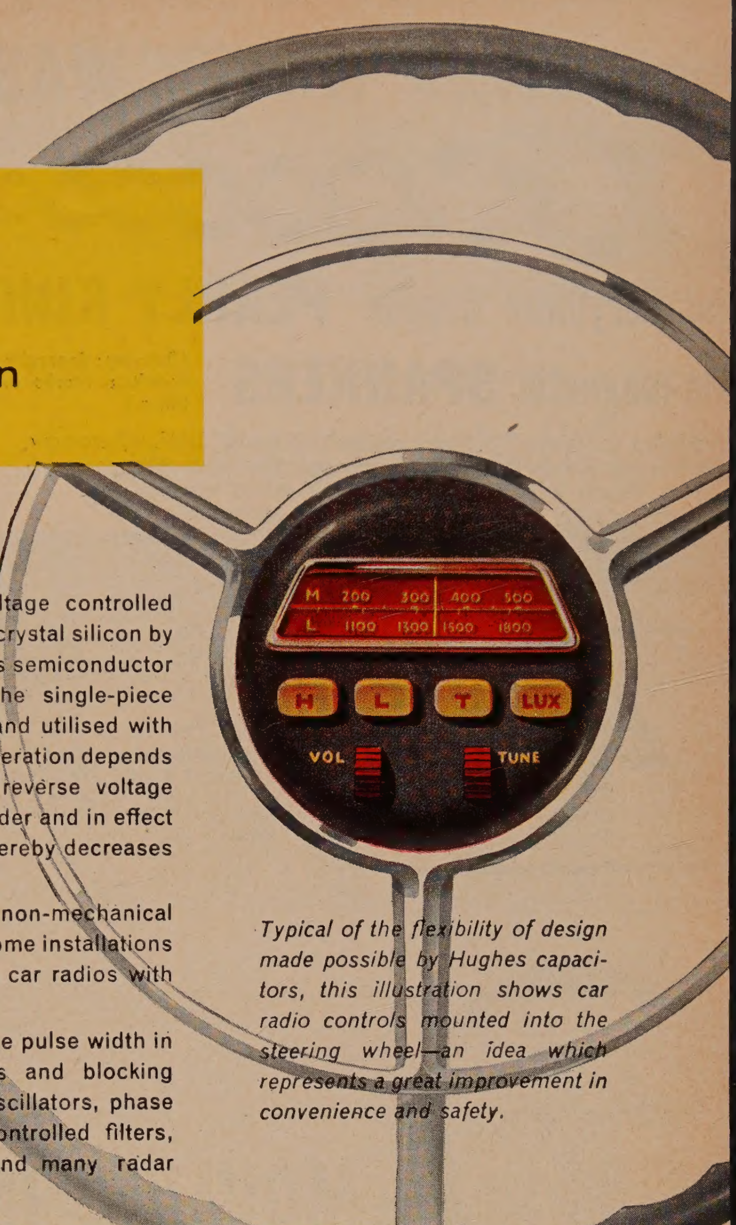

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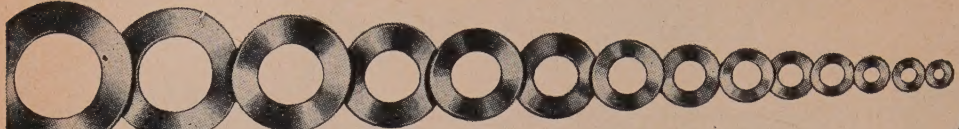

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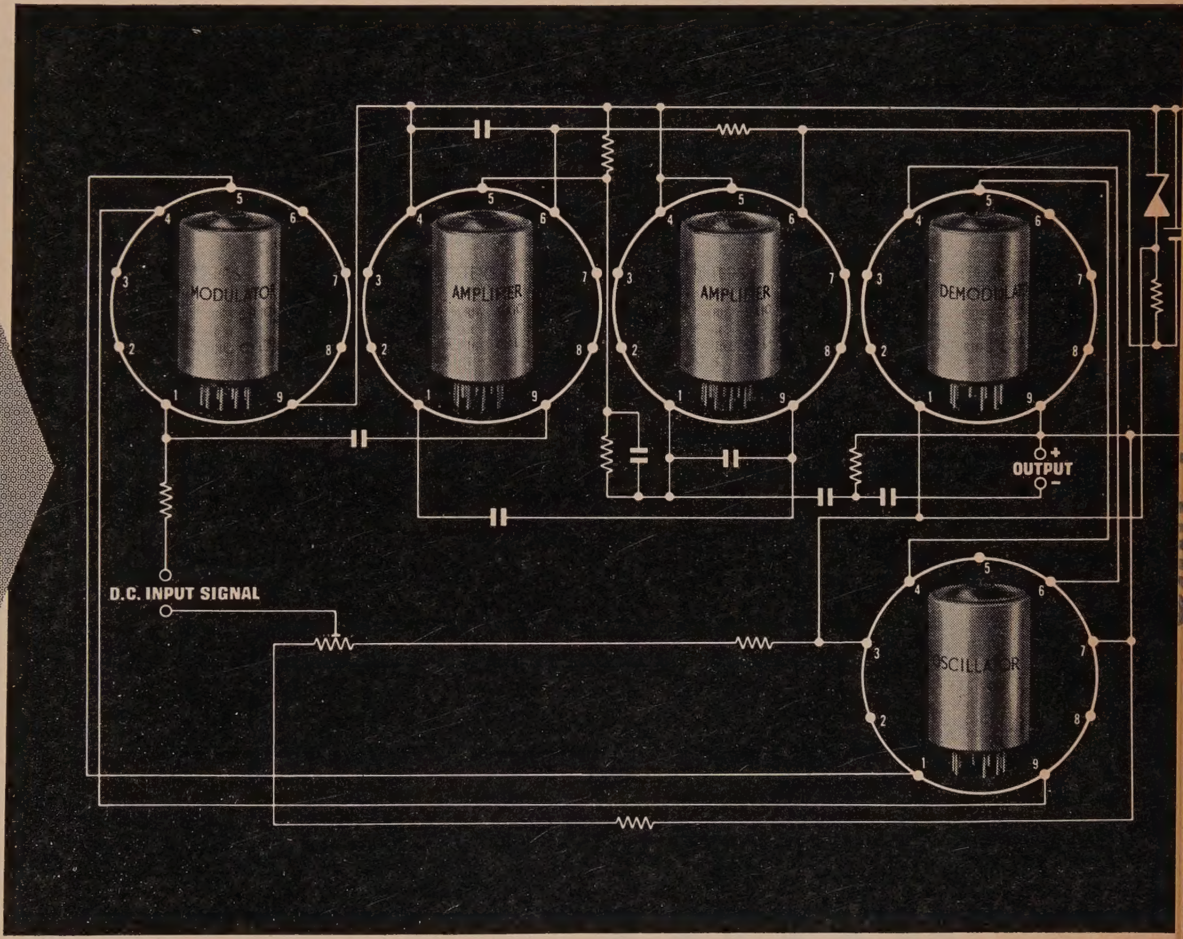

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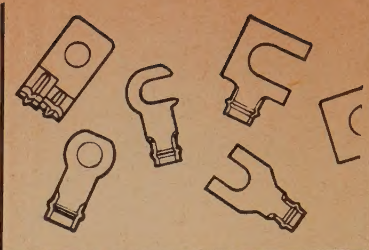

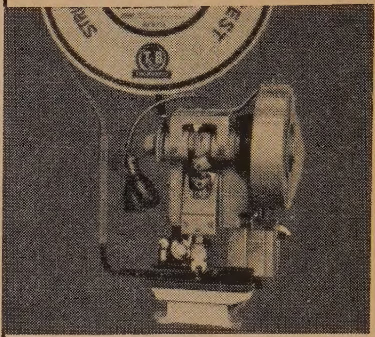

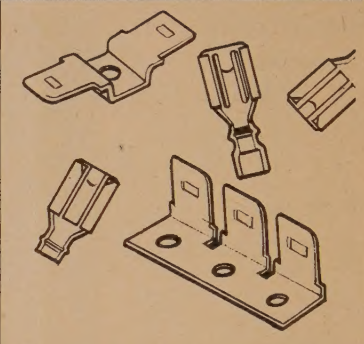

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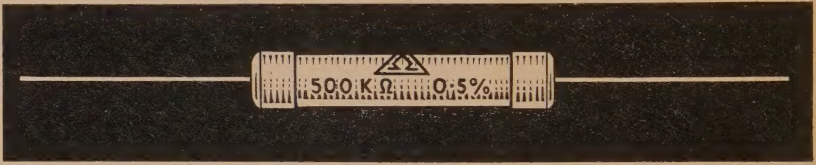

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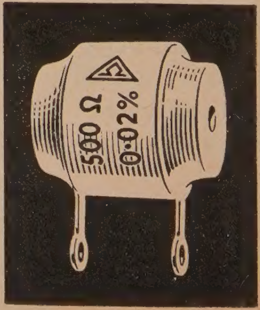

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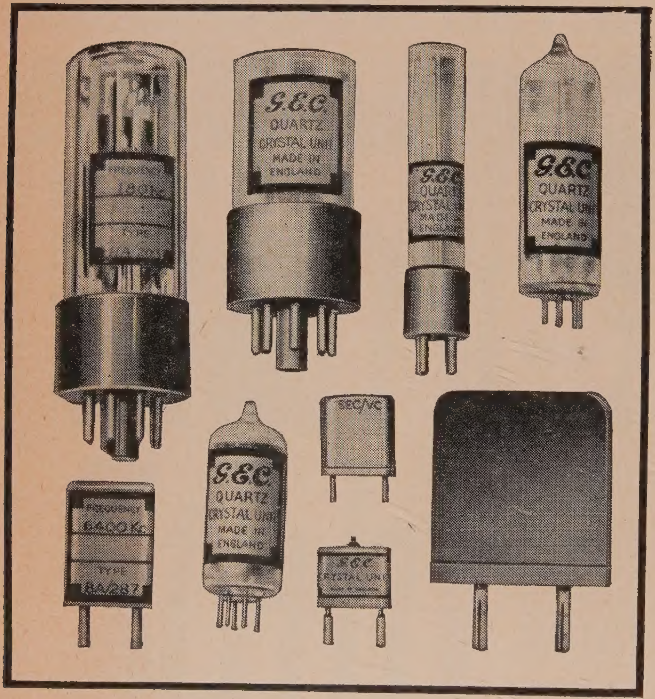

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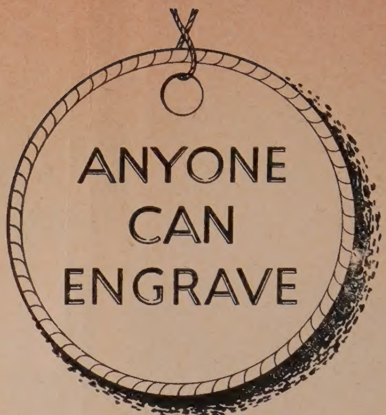

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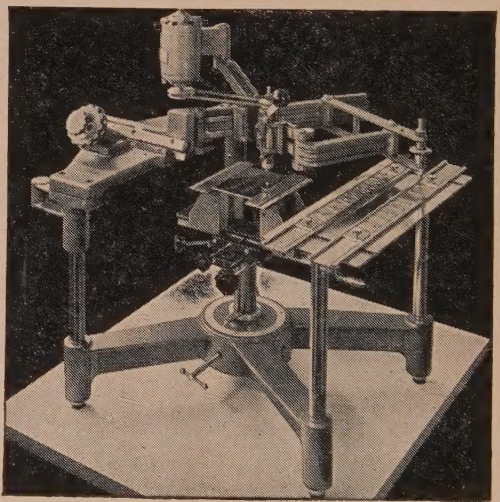

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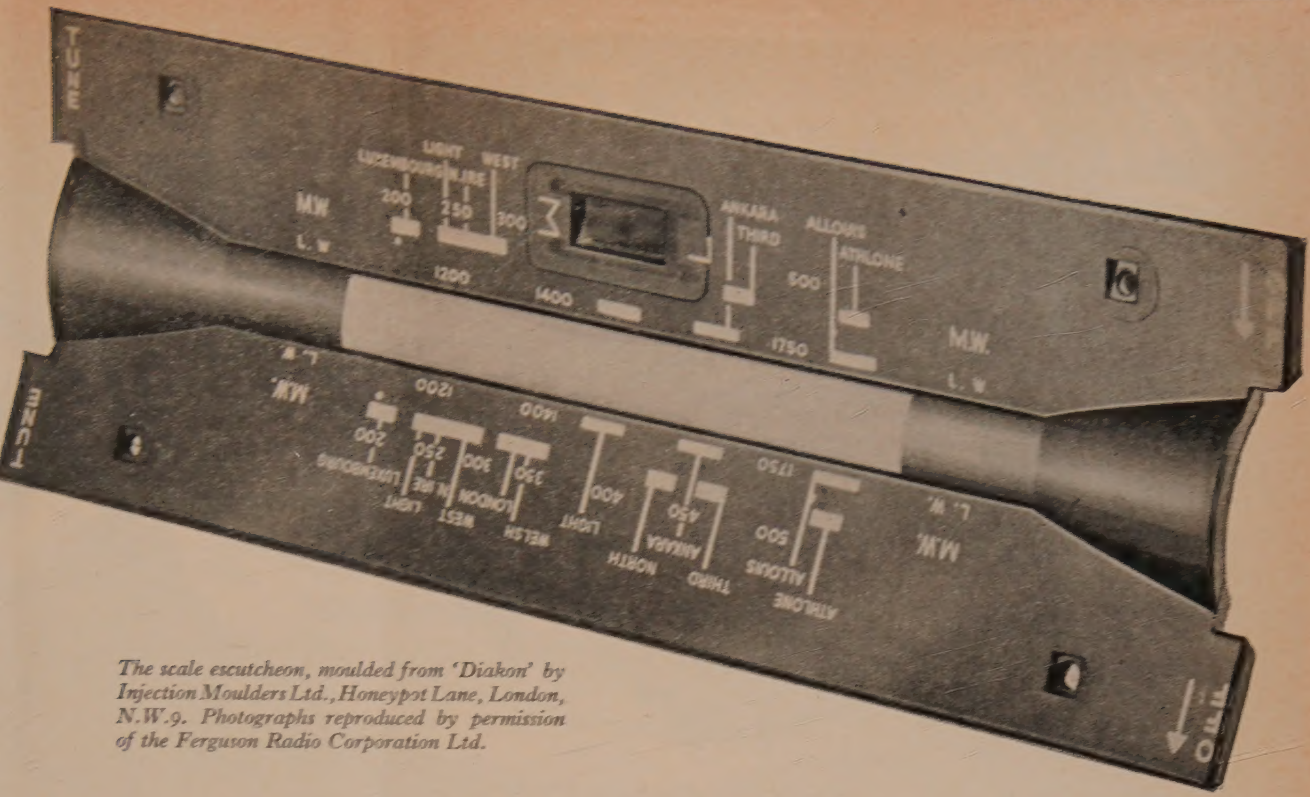

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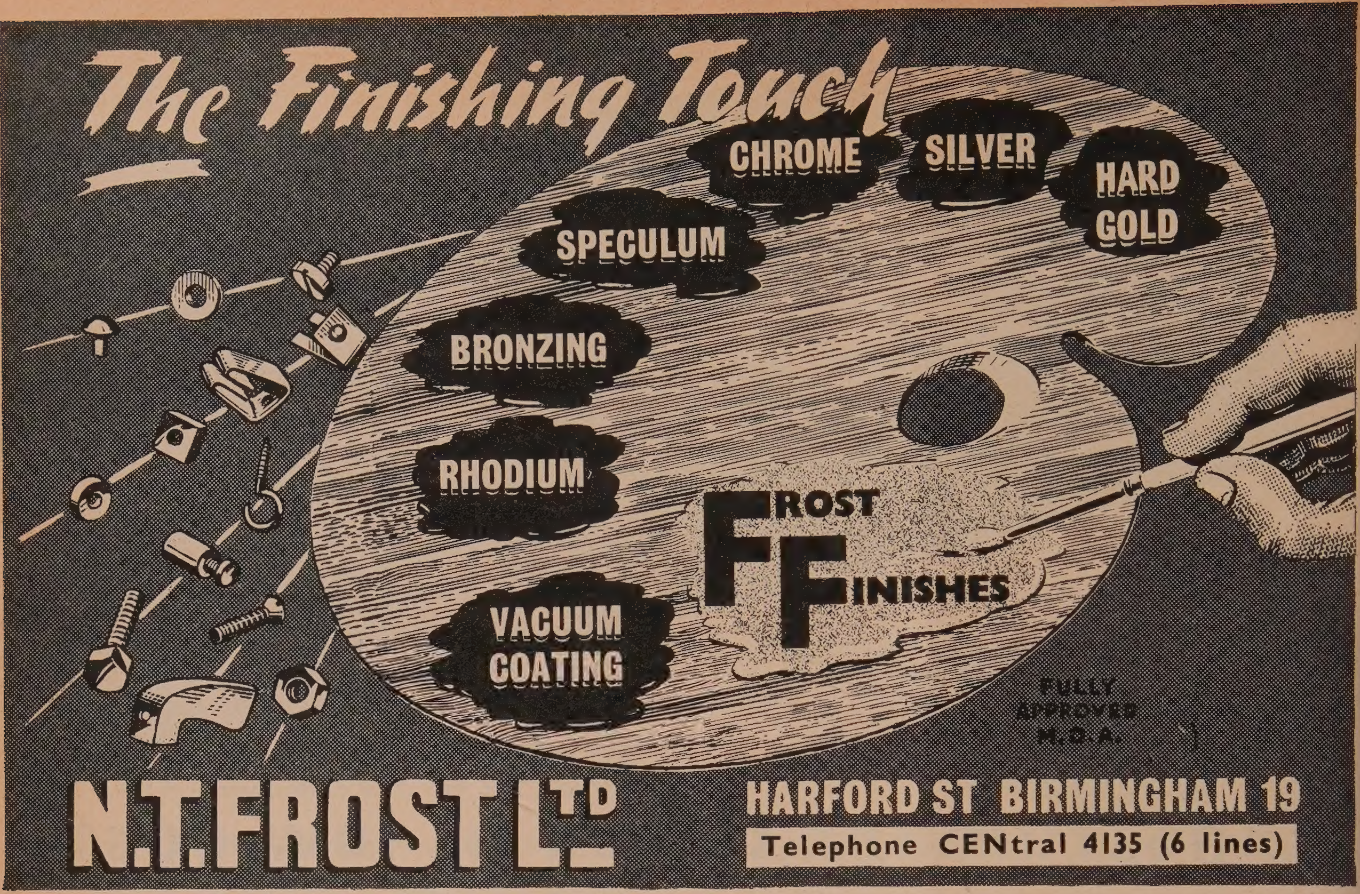

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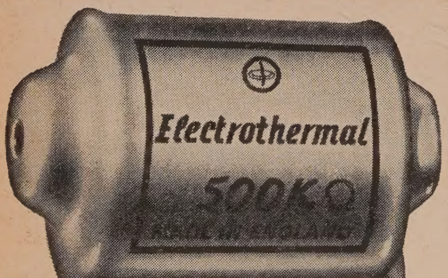

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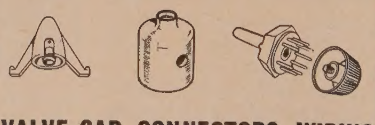

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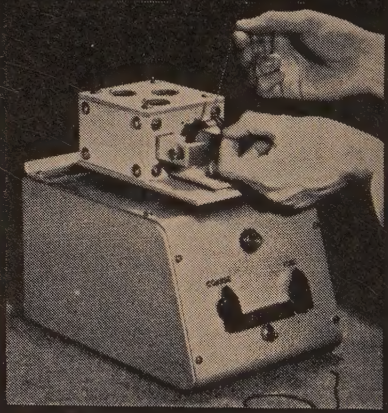

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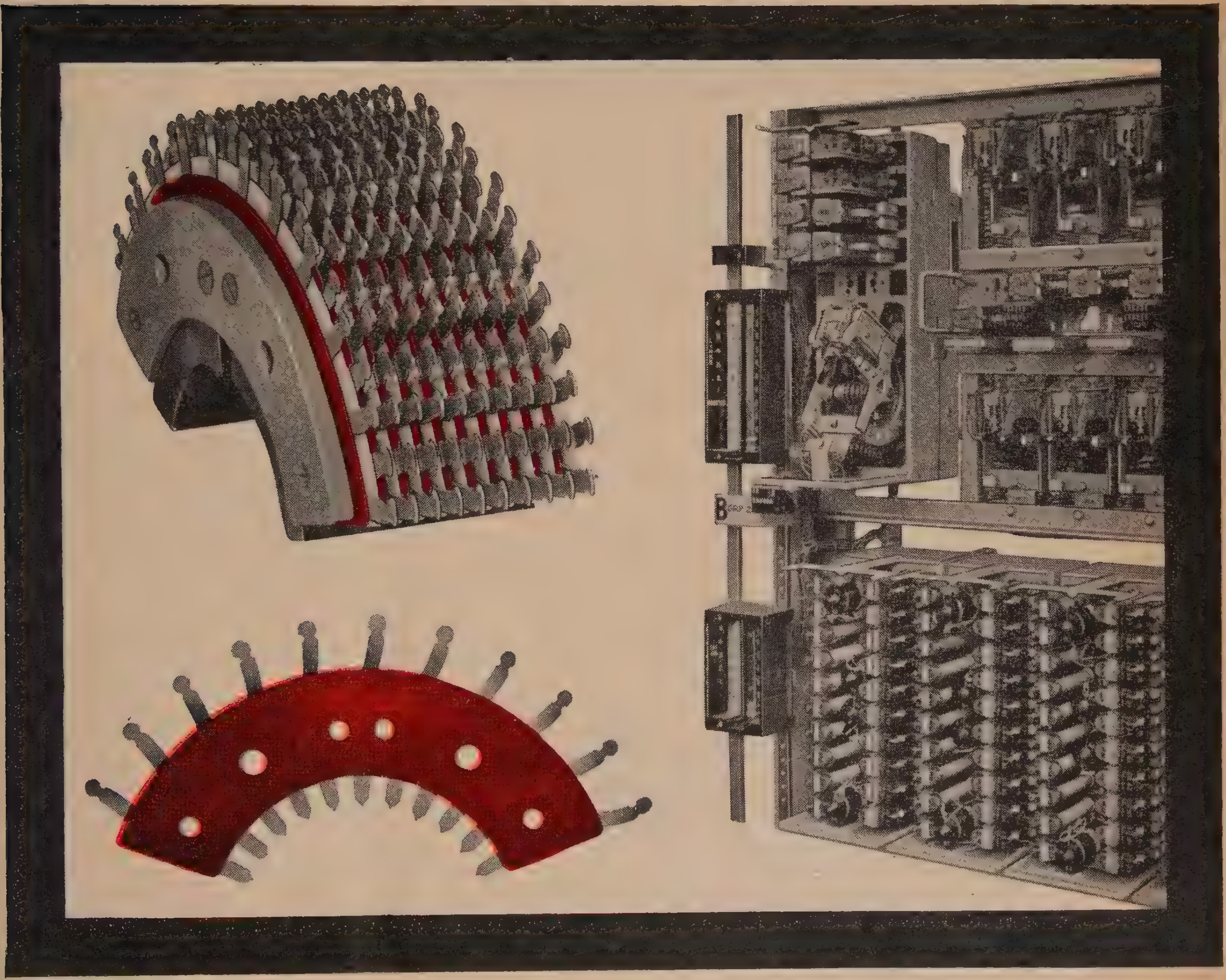

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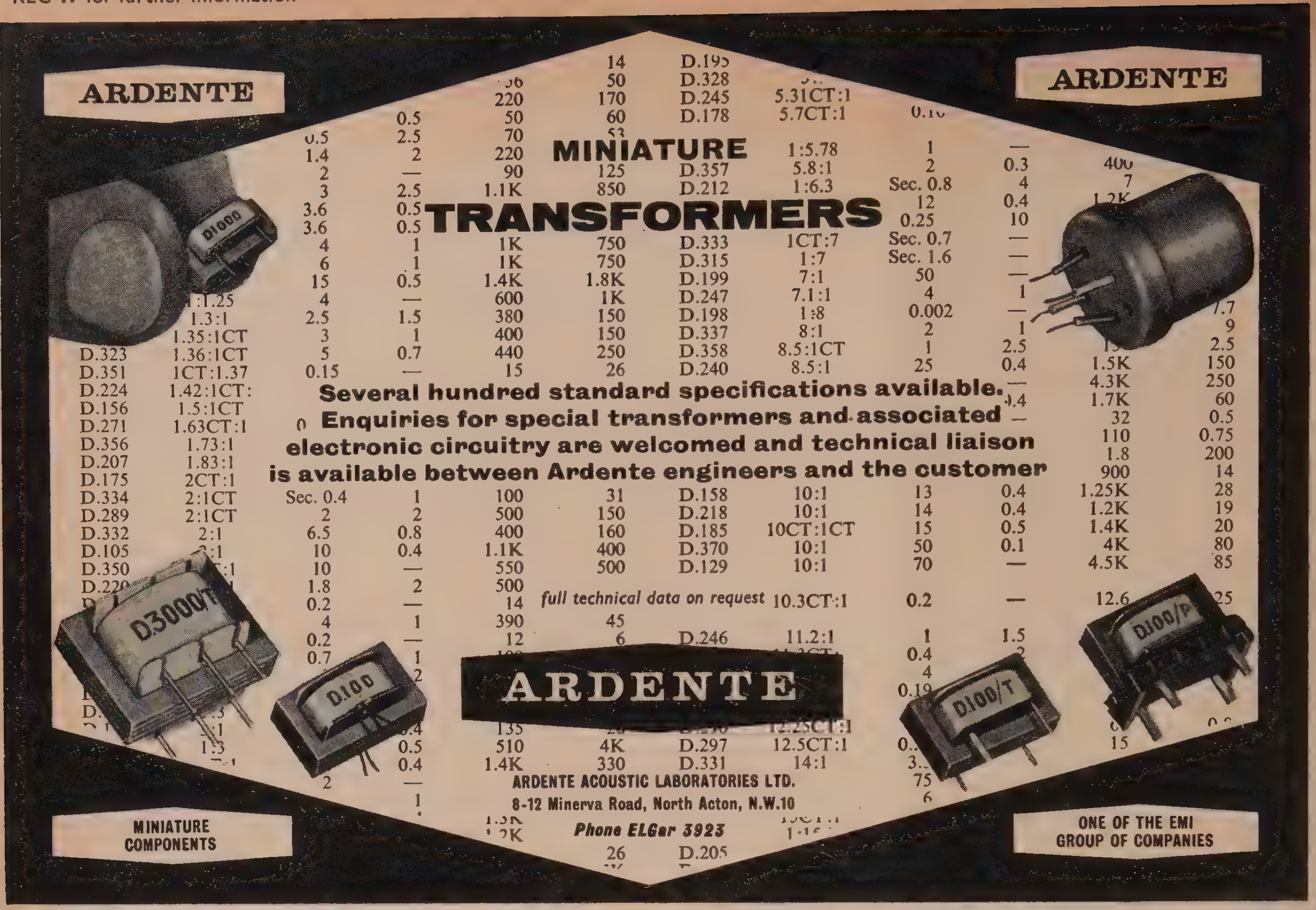

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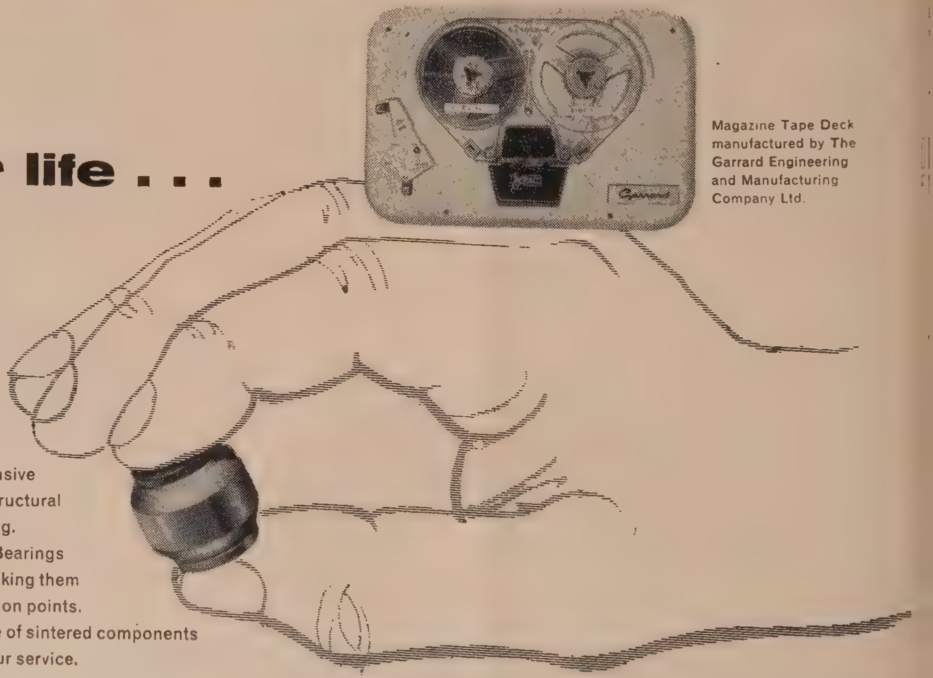

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DIMENSIONS (Indicate normal working tolerances) ……………………………………

MATERIALS USED ……………………………………

TEMPERATURE LIMITS (State whether vacuum or atmospheric) ……………………………………

FINISH REQUIRED ……………………………………

QUANTITY ESTIMATED ……………………………………

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AWARDS FOR WRITERS

The British Radio Equipment Manufacturers' Association
The British Radio Valve Manufacturers' Association
The Electronic Engineering Association
The Electronic Valve and Semi-Conductor Association
sponsor a scheme to award premiums of 30 guineas each for articles, which, in the judges' opinion, are likely to publicise throughout the world the valuable and original work taking place in the United Kingdom in radio, electronics and associated instrumentation.

RULES

(1) AWARDS. The constituent Associations are prepared to award up to 8 premiums of 30 guineas each to the writer or writers of eligible articles published between January and December in any one year. Some prizes will be awarded for purely technical articles as well as articles of commercial or interpretative merit.

(2) ELIGIBILITY. (a) Articles in any journal are eligible provided that the journal is available to the public generally, either by subscription or by open sale. (b) No articles can be accepted for consideration before publication in a journal eligible for the competition. In doubtful cases of eligibility the Panel of Judges shall decide. (c) The writers themselves must take the initiative and submit articles for consideration but this rule does not prevent acceptance of articles submitted by the editor of a journal. (d) Members of the Panel of Judges may select and submit articles for consideration by the Panel. (e) Candidates submitting articles must certify to the Secretary of the Awards Committee that they are not earning 25% or more of their income from fees for articles or from book royalties. When an article is by two or more authors each must be eligible under the above terms. In such a case the award of 30 guineas is shared between the writers. Any number of articles may be submitted by a single candidate.

(3) CRITERIA. The discretion of the Panel of Judges is absolute. They are, however, directed to take into consideration the following factors: (a) commercial or interpretative merit in the context of British achievement in electronics, (b) technical merit, (c) originality, (d) presentation and clarity.

(4) PROCEDURE. Persons submitting articles for consideration of the Panel should send seven copies of the article together with a signed declaration that the writer (writers) is (are) eligible within Rule 2(e) to the Secretary of the Awards Committee, c/o The Electronic Engineering Association, 11 Green Street, Mayfair, London, W.1, formally submitting the article for consideration for an award. All entries must reach 11 Green Street not later than the 15th January 1962. Articles should be submitted for consideration as soon as possible after publication. Presentation of the awards is made soon after selection, which takes place in March. The names of the prizewinners are announced in the technical press and each prizewinner receives a personal letter informing him of his success.

PANEL OF JUDGES

Prof. C. W. Oatley, O.B.E., M.A., Prof. Electrical Engineering, Cambridge University
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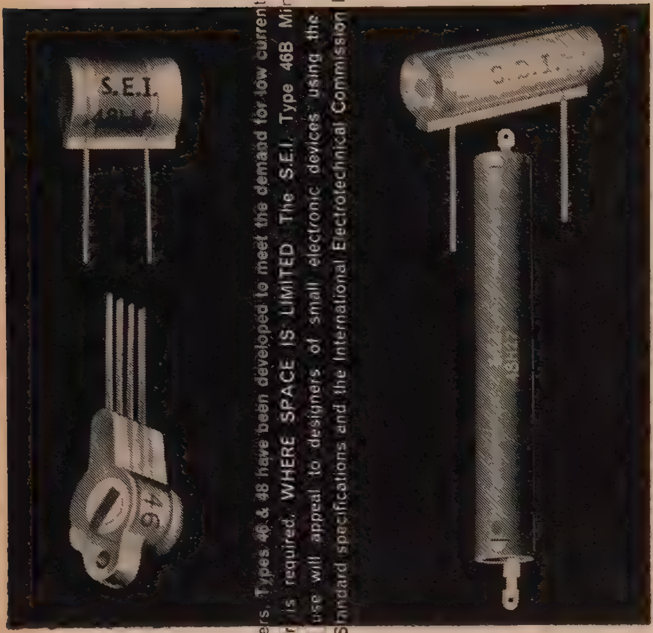

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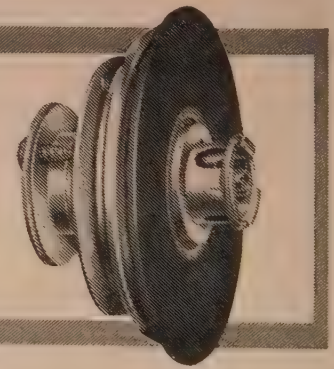

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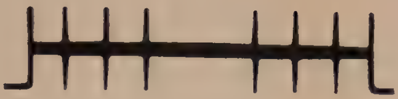

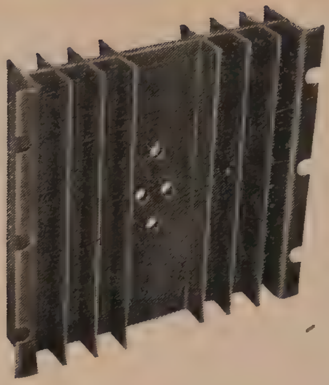

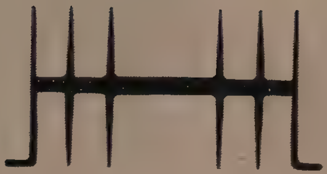

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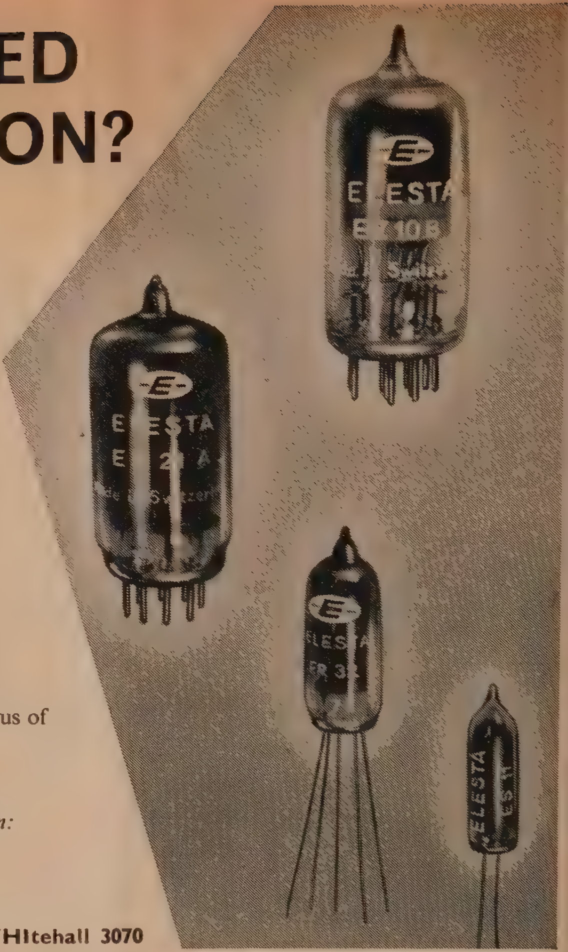

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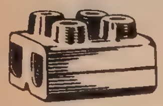

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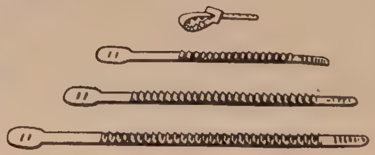

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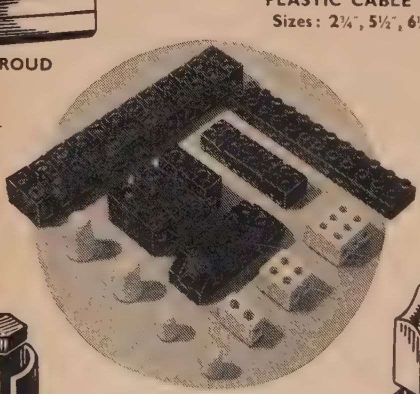

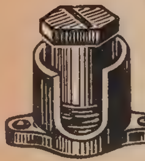

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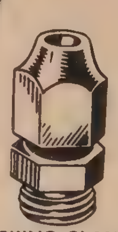

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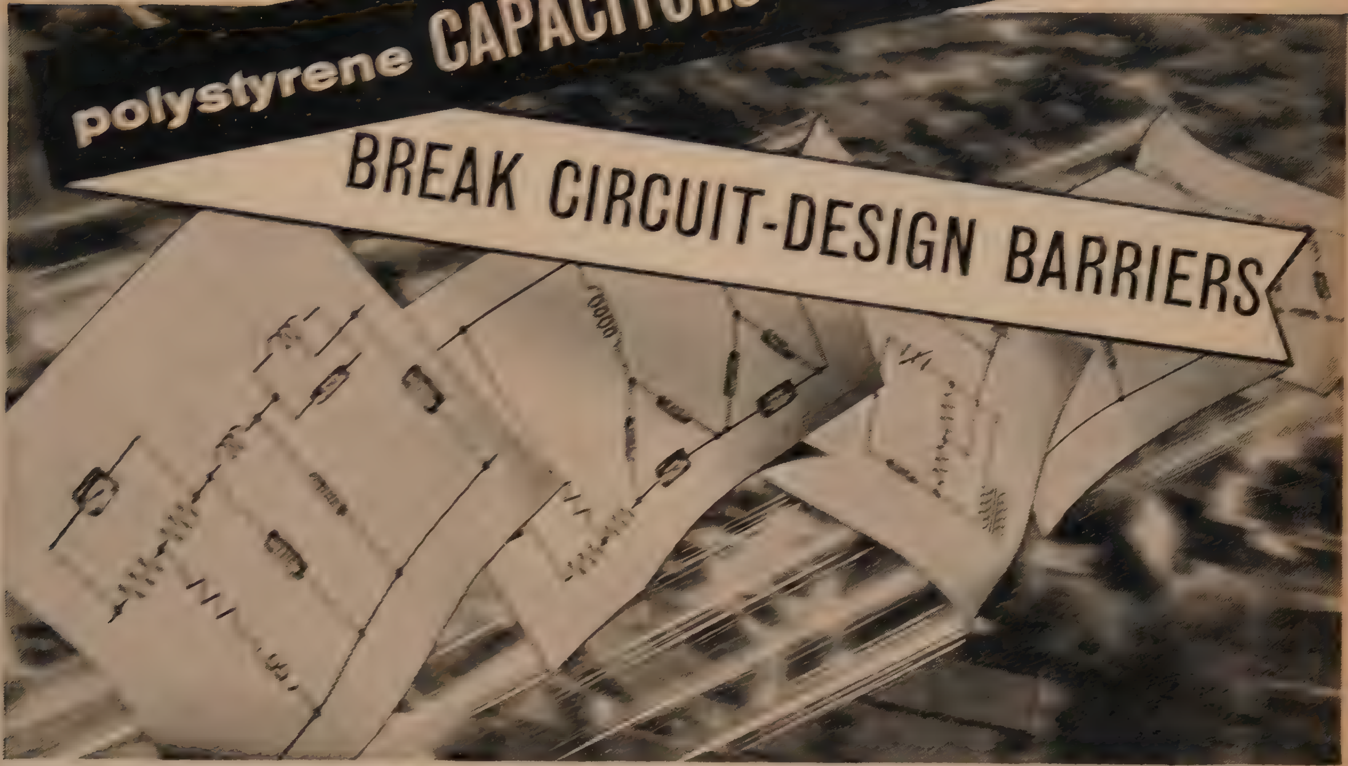

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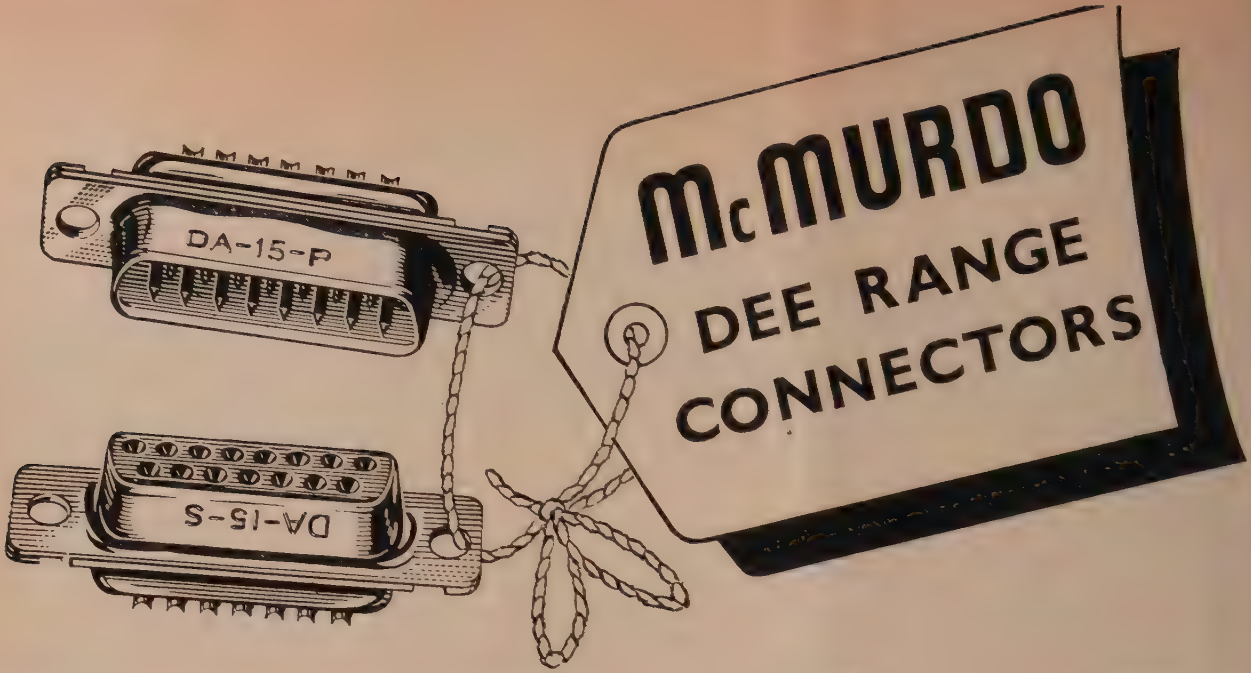

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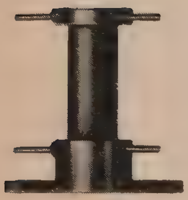
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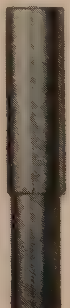

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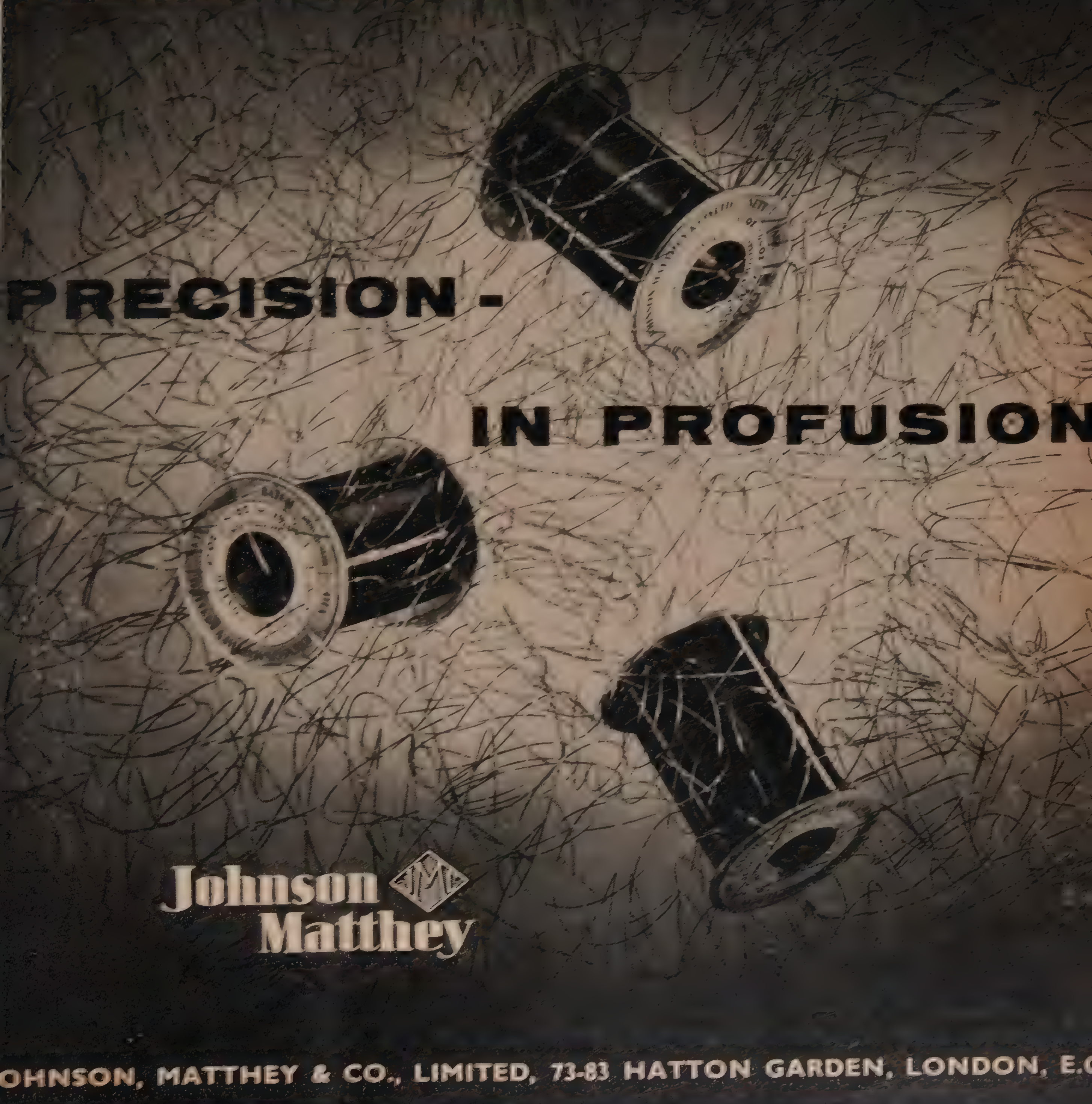

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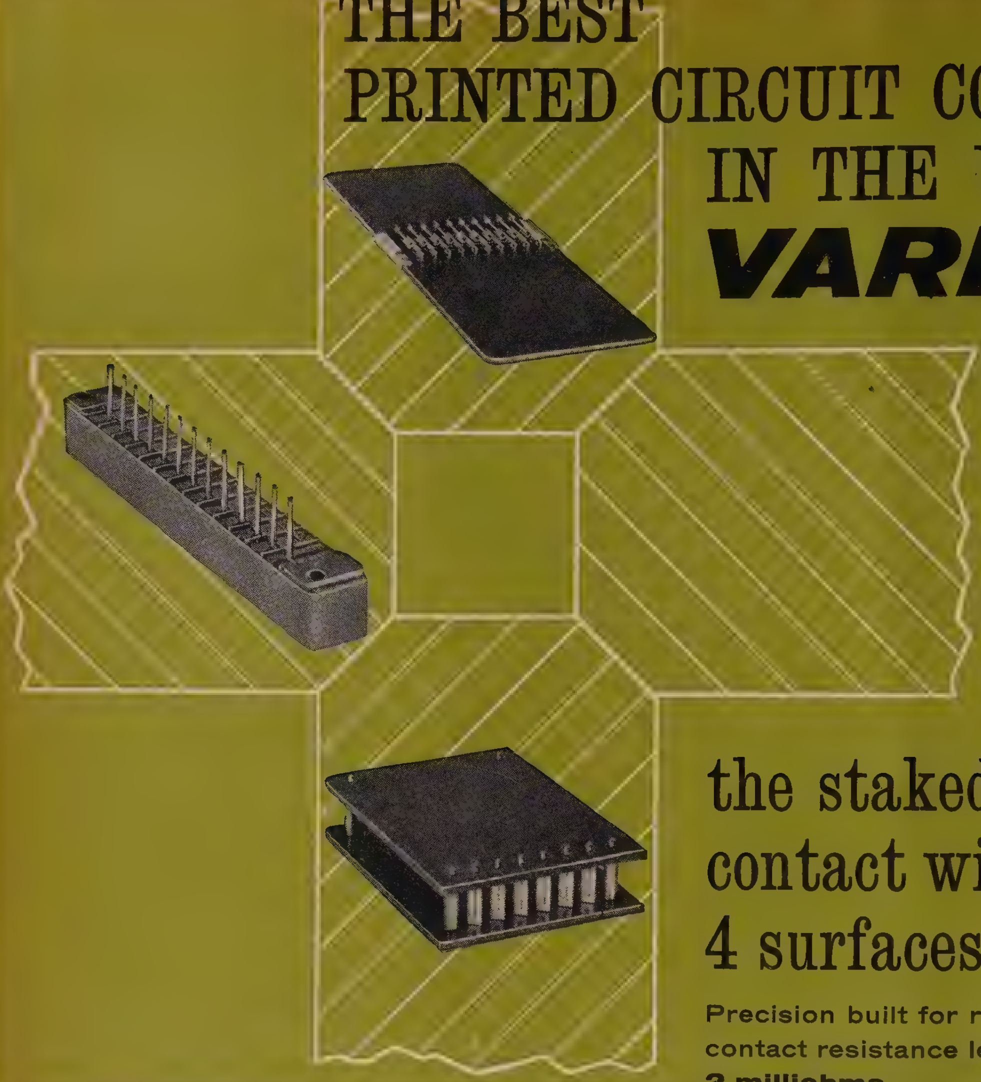

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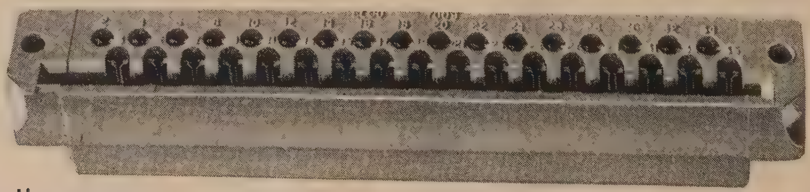

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Commentary

Design in Electronics

A POPULAR talking point these days seems to be the importance of design in the field of electronics. The main argument from outside the industry is that it would be much easier to sell in overseas markets if components, instruments and the larger electronic installations were designed in such a way that they would, in the aesthetic sense, immediately appeal to the eye of the prospective buyer.

Just how serious is this problem? To accept this kind of argument, one must believe that customers are initially more interested in how a thing is designed than in its performance and general standards of reliability. We find it difficult to believe that this can be true. It would appear that the only case where design becomes of real importance is in those instances where a buyer is faced with, for instance, two transformers for which are claimed similar performance characteristics. In these circumstances, preference might well be given to the better designed product. On the other hand, design often involves added expense—higher quality finishing materials must be used and the services of an experienced designer must be paid for. These factors will, inevitably, raise the cost of the product which then tends to cancel out the advantage it may have initially been given.

We have tested the ideas of a number of people directly connected with this problem. The general concensus of opinion is that good electronic equipment designs itself. Finishes are governed mainly by the conditions in which various products have to work, and where a complete equipment is involved, more care must be taken to distinguish controls—by means of colour combinations etc.—to ensure that semi-qualified operators can understand them. It has, in fact, become a fairly common practice to etch circuit layouts on control panels as an aid to the technically backward.

The Industry will have no difficulty in selling abroad provided that it keeps in step with present day requirements and ensures that prices are reasonable for the reliability claimed for a particular product. "Reliability" is, without doubt, the keyword in the electronics industry today. Unless our salesmen abroad can state, with confidence, that the goods they sell have been proved by severe tests to be absolutely reliable within the limits imposed by the manufacturer, then they will have a very difficult task. It only requires a series of failures in a particular batch of products to destroy a customer's faith in British goods as a whole.

Provided that buyers can be educated to specify exactly what they require and, even more important, the exact conditions in which the component, instrument or apparatus must work, then the salesman should have no difficulty in selling goods on the basis of their reliability with design coming into the picture as a "poor second" and purely as an added incentive

G. W. A. DUMMER

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RADIO & ELECTRONIC COMPONE

We are now able to announce that four distinguished scientists have accepted our invitation to form an Editorial Advisory Board for Radio and Electronic Components. Their advice is now freely available to the Editor on all aspects of editorial content and will assist

Mr. DUMMER joined the Royal Radar Establishment (then A.M.R.E.) in 1939 and worked on time bases, being associated with the design of the first P.P.I. to be used in radar, and later on radar synthetic trainers, for which he was awarded the M.B.E. He was also awarded the American Medal of Freedom (with bronze palm) by the United States of America for his work in this field.

In 1944 he began research and development on components and constructional techniques for radar equipments. He has written numerous papers on printed and potted circuit techniques and was awarded an I.E.E. Premium for a paper on this subject in 1953. He is the author of a series of books on "Radio and Electronic Components" published by Sir Isaac Pitman and Sons Ltd.

In addition to the 'Components' series, he has written *Modern Electronic Components* (Pitman), and with co-authors *Electronic Equipment Reliability* (Pitman), *Electronic Equipment Design and Construction* (McGraw-Hill), and *Miniature Electronic Components Data Annual* (Pergamon Press) etc.

He has travelled extensively and lectured in many countries.

Mr. GARTON is an Assistant Director of the Electrical Research Association. He was born in 1901 and his early education took place in Canada, and was continued at Rutlish School, Merton and at the Rugby College of Technology.

He began his career as an apprentice with The British Thomson-Houston Co. Ltd., Rugby in 1917 and remained with the Company until 1933. Mr. Garton then went to the All-Union Electrotechnical Institute in Moscow where he worked for four years. On his return to England, he joined the Materials Department of the Electrical Research Association and was appointed Head of the Department in 1946. His appointment as Assistant Director was made earlier this year.

Mr. Garton has written a number of original scientific papers and was elected a Fellow of The Institute of Physics (F.Inst.P.) in 1946 and a Member of the Institution of Electrical Engineers (M.I.E.E.) in 1954.

He was a Member of the Measurement and Control Sectional Committee of the I.E.E. during the periods 1954-6 and 1958-60, and was Chairman of the Section for the period 1960-61.

E. MENDOZA

F. M. RUSSELL

EDITORIAL ADVISORY BOARD

him to publish, each month, a well-balanced and carefully selected group of technical articles of interest to workers in all aspects of the industry, together with reports on the latest and more significant developments, ideas and techniques in the electronic components field.

Dr. MENDOZA was born in 1919. He won a scholarship from Manchester Grammar School to Trinity College, Cambridge, and there became a Senior Scholar. He was awarded a double first in physics in 1940, and started work at once at the Admiralty Signal Establishment on radio aids to navigation, notably on applications of the Decca system. After serving as a Lieutenant in the R.N.V.R. (Special Branch) he returned to Cambridge in 1946.

His work in low-temperature physics began with studies of heat transfer below 1°K, which have enabled reliable measurements of many properties of matter to be extended down to the lowest temperatures available. Later, Dr. Mendoza studied metals, notably the anomalies of electrical resistance, specific heat and thermal conductivity. He was awarded a Ph.D. in 1946, and became lecturer in physics at Bristol University and later Senior Lecturer at Manchester University. He has acted as Visiting Professor at Carnegie Institute of Technology at Pittsburgh, Pennsylvania, and at Padua University, Italy, and is a Consultant at Harwell. He played a large part in establishing the first organization, operated by the National Physical Laboratory, for selling liquid helium in bulk. His current research includes building a refrigerator designed to work at 0·1°K or below.

Dr. RUSSELL is engaged upon research work concerned with high energy particle accelerators. Born in London in 1931 and educated at Sir George Monoux Grammar School, he received his B.Sc. from London University at University College. For the following three years he worked upon high-power pulsed r.f. amplifiers and the theory of particle accelerators for which he was granted a Ph.D. from London University.

In the field of components Dr. Russell is the author of the recent series of articles on the use of transistors in experimental work. He has a patent on a precision wavemeter for use in the 75 Mc/s—1000 Mc/s range and is presently doing research on a new form of switch for use with electromagnetic pulsatance in the visible range of frequencies with possible applications in the communications field.

Dr. Russell joined the staff of A.E.R.E. Harwell in 1956 and in 1960 accepted a post with the National Institute for Research in Nuclear Science. For the last two years he has led a small research team in development work on particle accelerators.

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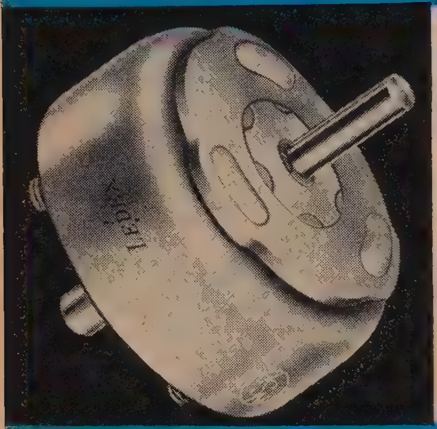

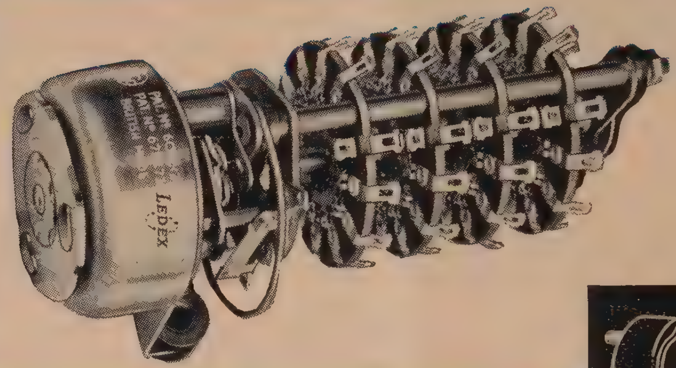

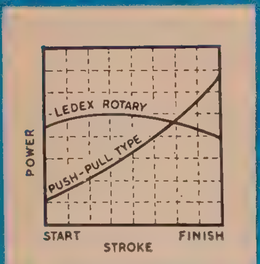

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SUPERCONDUCTING CIRCUITRY

An Introductory Survey

By E. Mendoza, Ph.D.*

At extremely low temperatures, some metals become superconductors. They have zero *electrical resistivity, but their normal resistance can be restored by a small magnetic field. New types of logical and storage circuits can be designed, which are very fast, are far smaller than the smallest corresponding conventional components and consume negligible power. The engineering difficulties of building suitable automatic liquid helium refrigerators seem near to being solved and it is apparent that this new type of circuitry holds immense promise for the future.*

Introduction

SUPERCONDUCTIVITY is a phenomenon which it is difficult to believe in. The idea that under the right conditions the electrical resistance of a metal can become zero—identically zero, not just a small value—is repugnant to common sense.

We are so used to the idea that all real processes in this world must be slowed up by some opposing force—electrical resistance, fluid viscosity or solid friction—that it comes as a shock to realize that, having been started, electrical currents can go on circulating in a superconductive circuit apparently for ever without any external voltage to maintain them.

The basic fact of infinite conductivity is indeed well established and so is the fact that the normal finite conductivity expected of a metal can be quickly restored by application of a small magnetic field. These phenomena are the origins of the very new types of switching and storage devices based on superconductivity. Some elementary ideas on circuitry have to be revised but this rethinking is well worth while.

A most significant feature is that superconductivity occurs only at very low temperatures, quite close to the absolute zero of temperature and attainable only by the use of liquid helium. Under such conditions (which are so far removed from ordinary experience that it is not surprising that "ordinary" laws of behaviour are violated) the phenomena of quantum physics become manifest—one of which is superconductivity.

At the same time the need for low temperatures imposes certain obvious practical restrictions on any circuitry. The components must be placed inside a vessel, which is thermally isolated from the room outside and which contains liquid helium. Till very recent years, the technical difficulties of producing and handling liquid helium were such that it was impossible to think of superconductive circuits as anything but fascinating devices necessarily confined to the research laboratory where the requisite highly skilled low-temperature techniques were available. But recently it has been demonstrated that liquid helium refrigeration can be brought to the same degree of push-button efficiency as ordinary domestic refrigeration. It is therefore possible to visualize superconductive components inside their refrigerator taking their place in say, a large computer, in conjunction with more conventional circuit devices. When planning circuits for use in the next few years, the fact that low temperatures are an essential part of their operation can for practical purposes be forgotten, and the concentration should be on the implications of circuitry with zero resistance.

Perspectives

To put these new developments into what might be called their historical perspective—though in the context of modern scientific discovery an event which occurred only a few years ago already belongs to ancient history—a few dates will be mentioned. Helium was first liquefied, and the very low temperatures were first made available, in 1908 in Leiden, Holland. The superconductivity of the metal mercury was discovered three years later. The magnetic basis of the phenomena was clearly recognized in the 1930's and the correct electromagnetic equations written down, though the origin of the phenomenon was shrouded in obscurity. At the time about half a dozen laboratories throughout the world had liquid helium available. Immediately postwar, low temperature research was greatly accelerated by the marketing of an American helium liquefier (producing liquid to be drawn off and transferred to another vessel) which took all the mystery and difficulty out of the production of the refrigerant—at the present there are something over 200 low-temperature laboratories in different places. Postwar research on superconductors was mostly concerned with their behaviour at high frequencies (short radio and infra-red wavelengths particularly) and this allowed the electronic band structure to be guessed at. The first attempt at a proper fundamental theory of the phenomenon, based on the modern theory of electrons in metals, was made in 1950; the Bardeen-Cooper-Schrieffer theory, accepted today as essentially correct, dates from 1957.

***The Physical Laboratories,**
The University, Manchester.

The idea of finding practical applications of superconductivity is quite recent. About ten years ago, superconducting electrical power transmission lines, with refrigerator stations every few miles instead of transformers, were discussed (and rejected). The first, primordial, circuit element—the cryotron—was suggested in 1956 by Dudley Buck of the Massachusetts Institute of Technology. Almost immediately huge sums of money were poured into research on superconductivity in all its aspects, principally, of course, in America where an enlightened government sponsors research on a vast scale, provided that the illusion is maintained that it is all undertaken by free enterprise. A number of different superconducting storage and logical devices were proposed, but the cryotron, modified almost out of recognition, has apparently survived them. It soon became apparent that these devices held the promise of great operating speed combined with very small size and negligible power consumption—characteristics which are most attractive to designers of computers. Research on the design of automatic refrigerators—as opposed to liquefiers—began about two years ago in the U.S.A.

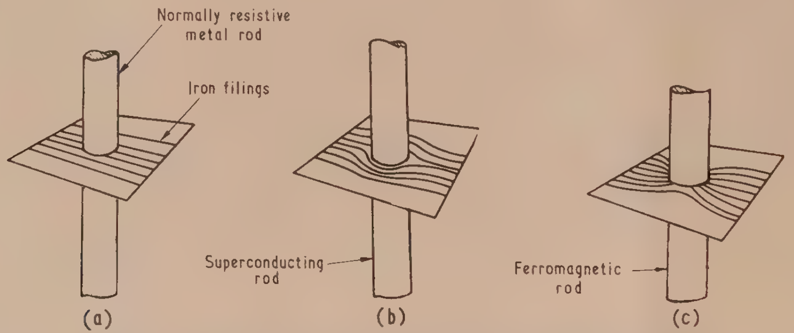


Fig. 1. Field patterns of rods in horizontal magnetic fields. *(a)* an ordinary metal (permeability nearly 1) does not affect the field; *(b)* a superconductor expels the field; *(c)* a ferromagnetic concentrates the field.

In parallel with this activity, other completely different applications of superconductivity have been followed up. Very sensitive infra-red detectors have been made, though it is not easy to engineer them out of the laboratory stage. The repulsive force exerted on magnets, allowing them to be stably levitated in the vicinity of superconductors, has led to the design of almost frictionless bearings for motors and gyrocompasses. Within the past year it has appeared that superconductors might be used to produce incredibly large magnetic fields over large volumes with the expenditure of no electrical power. There is even a theoretical prediction—not at all widely accepted—that such magnets might be found to work at room temperature.

The Facts of Superconductivity

About half the metallic elements become superconductors; mostly they are those metals which have high electrical resistance at ordinary temperatures. Thus (to select a few examples) niobium has its transition temperature, written T_c, at 7·8° above absolute zero (written 7·8°K) below which temperature is a superconductor. Lead undergoes its transition at 7·2°K, tantalum at 4·3°K, tin at 3·7°K, zinc at 0·9°K and hafnium (the lowest transition temperature known) at 0·3°K. Copper and the noble metals remain normal and resistive at all temperatures.

It is perfectly accurate to say that when a wire of suitable metal is cooled gradually, while its resistance is measured by a potentiometer arrangement, the resistance is found to fall very suddenly to zero as the temperature reaches the value T_c. The temperature interval in which the change takes place is a very narrow one—one-thousandth of a degree above T_c the metal wire has its full resistance (at any rate if it is pure), one thousandth of a degree below T_c the resistance is zero.

This statement, implying that superconductivity is concerned purely with the electrical resistance of the metals concerned, is however not a complete description of the phenomenon. Superconductivity is most accurately described as a *magnetic* phenomenon. This idea will now be developed in some detail.

Magnetic Behaviour

Probably the most revealing experiment is to place a long vertical rod of the metal in a small horizontal magnetic field (Fig. 1). Since the magnetic permeability of any non-ferromagnetic metal is almost exactly equal to unity, the lines of force (revealed by iron filings sprinkled on a piece of paper round the metal) take no notice, as it were, of the presence of the metal. (Note that if the rod were ferromagnetic the lines of force would be distorted so as to be pulled into the rod, corresponding to its high permeability.) Now let the rod be cooled to some temperature where it becomes superconducting. The pattern of the lines of force changes—the lines are all *pushed out* of the metal showing that a magnetic field cannot exist inside it; the permeability is zero. If the temperature is held constant but the external magnetic field changed by a small amount, the lines of force still do not enter the metal; the field inside the bulk of the metal must remain zero. It is the fact exactly cancelled out by currents flowing in a very thin layer close to the surface of the metal. The thickness of this layer, usually of the order of 10^{-6} cm., is called the penetration depth and it is obvious that the external magnetic field does penetrate the metal to this depth.

When the magnetic field is increased by a *large* amount, however, it does penetrate inside the bulk of the metal. It is easier, for the moment, to imagine a slightly different set-up from the one just described, in which the applied magnetic field is not transverse to the rod but parallel to it. Then as the field is increased it all penetrates suddenly, at a value called the critical field, written H_c. For lead, H_c is zero at the transition temperature $T_c=7{\cdot}2$°K, rising to 570 gauss at 4°K and 790 gauss at 1°K. Data for some typical metals are shown in Fig. 2.

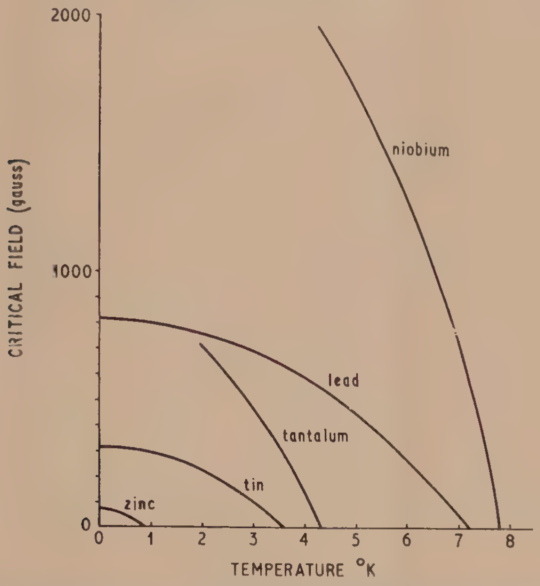


Fig. 2. Critical field H_c as a function of temperature for some superconductors. For each metal, T_c is the intercept on the temperature axis; the metal is superconducting in the region underneath the curve, resistive outside it.

Returning to the more complicated case of the transverse field, it begins to penetrate when it has a value nearly equal to $H_c(1-e)$ where e is the demagnetizing factor of that shape of rod ($\frac{1}{2}$ for a cylinder), reaching complete penetration when equal to H_c. This rule has to be modified in practice however, since in the "intermediate state" when the field has partly penetrated, the metal breaks up into resistive and superconducting domains and the resistance of a 1 mm diam. wire begins to be restored at a value nearer to $0{\cdot}6\ H_c$ rather than $0{\cdot}5\ H_c$.

From the existence of the critical field, it follows at once that a superconducting wire can carry a certain maximum current before the field generated by the current itself drives the wire resistive. This maximum current is greater for a thick wire than a thin one, being determined by equating the tangential field at the surface to the critical field:

$$2i/10a=H_c$$

where i is the current in amps and a the radius of the wire in cm.

We now consider another experiment in which the metal, instead of being a rod, is in the form of a ring or loop. Consider this to be at a high temperature and let an external magnetic field thread the loop. Now let the metal be cooled to some temperature T below T_c and let the field be removed. The loop goes superconducting as soon as the field reaches some value H (depending on the value of H_c at the temperature T but modified by demagnetization effects). The rule now is that eddy currents are induced in the loop *which keep the flux threading the loop constant*. This is the fundamental rule of superconducting circuitry. Thus, if the external field is reduced from H to zero, a circulating current is induced in the ring, which persists unchanged so that flux is always trapped in the loop.

Consequences of the Magnetic Behaviour

With these magnetic experiments in mind, let us now establish the connection with electrical resistance. Consider first a wire with no current flowing in it; let a current now be established in it through an external circuit. We know that the rule is that no magnetic flux exists inside the bulk of the wire. Hence there can certainly be no change of flux linkage with time, and by Faraday's law of induction there can be no electromotive force. So a voltage can never be established inside the metal; hence the magnetic condition leads to zero electrical resistance.

Secondly, consider an eddy current of magnitude i_o induced in a loop of normally resistive metal. We ask how long it will take for this current to be dissipated as Joule heat. Since there is no external voltage, the ohmic drop of voltage round the circuit must be balanced by the self-inductive voltage; then

$$L\,di/dt=-Ri$$

or

$$i=i_o\exp(-Rt/L)$$

where R is the resistance, L the self-inductance of the loop. For a copper loop of one turn of 1 mm wire, 1 cm in diam., these have values of the order of $4{\cdot}10^{-4}$ Ω and 10^{-7} H, so the eddy current becomes negligible after a hundredth of a second. But in an experiment conducted some years ago, no change (to about 1 part in 1,000) could be detected in the magnetic moment of a superconducting lead ring with a current flowing when it was left in liquid helium for two years (fifty million seconds). Hence, experimentally the resistance of superconducting lead is certainly less than that of copper by a factor of about 10^{12}, and it is a fair guess that it is zero. Incidentally, it will be mentioned that the current in the ring was a few hundred amperes (being limited by the self inductance) but no power was dissipated because of the zero resistance.

Two odd points will be mentioned here. Firstly, the *thermal* conductivity does not exhibit any increase when a metal becomes superconducting; instead it actually decreases, largely because a proportion of the electrons are prevented from taking part in the ordinary thermal motion, being forced into energy states separated from the conduction band by a gap. Secondly, the conductivity at very high frequencies begins to become finite. Usually this fall-off takes place above the thousand megacycle region.

Circuits in Parallel

When two resistive circuits are in parallel the current divides in inverse ratio of the resistances of the two paths. When one is superconducting *all* the current goes through this branch, however small the resistance of the other.

When *both* are superconducting, we have to consider the conditions when the circuit is originally switched on. The voltages across both paths are then only those due to self-inductive back e.m.f.'s, so that if the subscripts 1 and 2 denote the two branches,

$$L_1 \,.\, di_1/dt = L_2 \,.\, di_2/dt$$

at all times. Hence in the steady state

$$L_1 \,.\, i_1 = L_2 \,.\, i_2$$

and the current divides in inverse ratio of the inductances.

The Cryotron

The cryotron was the first circuit element which was proposed for possible large-scale use. It was a relay which could have either zero resistance or a small but nevertheless finite resistance. Because of the rules just enunciated, this simple device opened the possibility of fascinating new switching circuits.

In its original form, Fig. 3, it was meant for operation at 4·2°K, the temperature of liquid helium boiling at atmospheric pressure. The gate consisted of a tantalum wire of diameter 0·009 in., covered with very thin insulation. The control winding was a tiny solenoid of insulated niobium wire 0·003 in. in diameter. The whole assembly was about half an inch long. Since the critical fields at 4·2°K of tantalum and niobium were respectively about 50 gauss and 1,000 gauss, a current of 10 mA in the control winding could drive the gate resistive while leaving the control winding always superconducting.

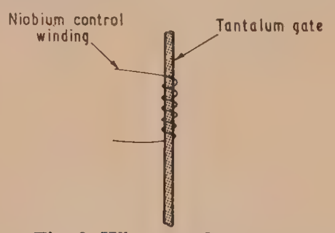


Fig. 3. Wire-wound cryotron.

The gain of the device was defined as the maximum current that could be carried by the gate divided by the minimum control current needed to switch the gate. This had to be greater than unity if one cryotron was to be able to control another. Adequate gain was achieved by the use of different diameters of wire.

The Cryotron Loop

An important basic circuit is illustrated in Fig. 4. A current of 10 mA is fed from an external source into the two branches of the circuit which are in parallel. Each branch consists of the gate of a drive cryotron (whose control winding can be driven from outside) in series with the control of another, called the sense cryotron (whose gate can lead into other circuits). It will be shown that this circuit is bistable, one state being with all the current flowing in the right hand branch, the other through the left.

Imagine the circuit to be all superconducting, with no current in the control windings of the drive cryotrons, and with 5 mA (half the total) in the control windings of the sense cryotrons so that those gates are also superconducting. Now let a short pulse be put in the control winding of the left hand drive cryotron so that its gate is driven normal. The current now flows wholly in the right hand branch and the gate of the sense cryotron is driven resistive. Note that while the drive pulse is at its maximum the loop as a whole is not superconducting. Now let this pulse be reduced to zero. At some instant it falls below the minimum needed to make its gate resistive and the loop as a whole goes superconducting again; from that moment on, the flux through the loop must not change. This total flux is that from the right hand branch only; the flux from the control winding on the left hand does not actually thread the circuit. Therefore, as this latter current dies down to zero the current on the right cannot change. (It cannot, for example, redistribute itself equally between the two branches because the net flux through the loop would then be zero.) This is, therefore, one stable state of the circuit. It can readily be seen that a further pulse on the same left-hand drive cryotron does not disturb this state but that if the right-hand drive is pulsed the loop settles down to its other stable state with all the current on the left.

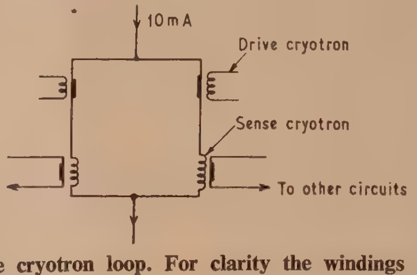


Fig. 4. The cryotron loop. For clarity the windings are shown outside the gates.

Since the sensing gates can control other circuits we have the basis of a system capable of binary arithmetic or storage with read in and read out.

Two features of this circuit will be mentioned. First, no energy is dissipated except at the instant of changeover from one state to the other. Then, the energy stored in the inductance of one control, $\frac{1}{2}Li^2$, has to be dissipated as heat. With proper design, this can be as low as 10^{-8} ergs; it would need 10^{13} cryotron flips per second to dissipate one watt. It is this fantastically low power that makes operation in liquid helium possible. Secondly, when the current is changing over from one state to the other the circuit effectively consists of the inductances of the control of two cryotrons in series with the resistance of the gate of another. Thus if all the cryotrons have identical characteristics the time constant for this switching process is twice the L/R ratio for any one cryotron.

The disadvantage of the original design was the comparatively large inductance of the solenoidal winding combined with the small gate resistance which gave a switching time of several hundred microseconds. Other bad features were the difficulties of fabrication and of welding the fine wires together.

The Crossed Film Cryotron

The crossed film cryotron avoids all these difficulties. Since evaporated metal films are used instead of wires, tin and lead are used for the metals since niobium and tantalum are extremely difficult to evaporate. The superconducting transition temperature of thin films is usually higher than that of specimens of the bulk metal. For the tin films commonly used for these cryotrons the transition lies between 3·7° and 3·8°K, so the operating temperature is usually a little below 3·7° where the critical field of the tin gate is small but that for the lead film is large enough for it to carry a current of a fraction of an amp.

The construction of a single cryotron is shown in Fig. 5. The control—called the grid—simply crosses the gate at right angles, with a thin evaporated film of silicon monoxide (SiO) in between for insulation. The magnetic field from the control grid can penetrate the lead gate even though the geometry is not as convenient as with the solenoid of the wire wound cryotrons, but, of course, the inductance is reduced by an enormous factor and the resistance of the gate is large because of the small thickness.

To achieve current gain, the control grid is a factor of 5 or so narrower than the gate (compare the diameters of the wires in the original wire-wound cryotron). To reduce the time constant, it would at first sight appear that the thickness of the gate should be made as small as possible in order to increase its resistance. However it has been found that the penetration depth is not truly constant for any metal at a given temperature but varies with the thickness of the specimen when this is small. It follows that, for a given gain, there is an optimum thickness of gate of about 0·5—1 μ to minimize the time constant.

For the comparatively large cryotrons of the kind often used now for experimental studies, typical dimensions are: the gate between 500 μ and 2,000 μ ($\frac{1}{2}$ mm—2 mm) in width and 0·3 to 0·8 μ thick; the insulating layer about 0·5 μ thick; the control grid between 25 and 125 μ in width and about 1 μ thick. The whole assembly is usually covered with SiO for protection. Since the wavelengths of visible light lie between 0·3 and 0·7 μ the films are transparent but strongly coloured by interference and the evaporated circuits have an abstract beauty all their own. A few miniaturized circuits have been tried with widths about a factor of ten times smaller (gate width 50 μ, half the thickness of a human hair, and the control grid width 12·5 μ).

Refinements

A very interesting development is the use of a superconducting ground plane to decrease the time constant further. This plane is a comparatively thick sheet of lead, about 2 μ thick, placed as close as possible to the gate strip but insulated from it. Its function can be thought of crudely as the opposite to that of an iron sheet near to a wire which by increasing the flux near the wire increases its inductance. Here, by contrast, the fact that the magnetic field from the gate can hardly penetrate the superconducting ground plane means that the inductance of the gate is decreased.

Another refinement is to increase the gain (for a given time constant) by the use of a bias field. This field is produced by a suitably placed strip carrying a steady current and adds to that produced by the control grid so that a comparatively small control current can switch the gate.

Recent developments include the use of "in line" cryotrons in which the control grid is parallel to the gate, not at right angles to it, so that a greater length of gate is driven resistive.

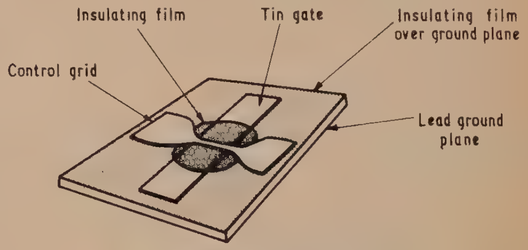


Fig. 5. Single crossed film cryotron.

Technical Problems

Circuits are printed by evaporating the high purity metals and the silicon monoxide insulator through a series of masks or stencils. The evaporation takes place, of course, *in vacuo* and the positioning of the masks has to be controlled from outside. Usually the rate of deposition of the films is quite high—of the order of 100 Ångström units of thickness (that is, 10^{-6} cm) per second.

A number of problems present themselves. The reproducibility of the elements depends very much on the absence of strain in the thin films. The difficulty here is that they are for convenience deposited at room temperature and then cooled to the low temperature, when differential contraction between the films and the substrate causes strains to set in. However, it has been found that a glass substrate covered with a thin layer of silicon monoxide behaves very well and the reproducibility of elements deposited on it is good. Another important factor is the need for high purity in the evaporated metals—dissolved gases cause lack of sharpness in the transitions. At first great precautions were usually taken to maintain an extremely high vacuum during the evaporation but it was eventually found that as long as the partial pressure of oxygen in the vacuum was maintained less than $5 \cdot 10^{-8}$ mm, comparatively low vacua (about 10^{-5} mm total pressure) could be used; hydrogen, carbon dioxide and water vapour should also be eliminated as far as possible. A second problem has been due to the presence of the "penumbra" at the edges of the evaporated areas. If the thickness of the film does not fall abruptly to zero but tapers off, the changes of transition temperature and penetration depth with thickness can lead, for example, to a situation where the edges of a gate are superconducting while the greater part of the width of the specimen is resistive. The superconducting edges short out the resistive bulk. Alternatively, if there are regions near the edges of a control grid circuit which are resistive while the greater part of their width is superconducting, a pulse travelling along is smeared out, since the velocities (comparable with that of light) are different in the two regions. A good deal of work has consequently been done on these penumbra. The edges have been sharpened most ingeniously by heating the substrate (which must be very clean) during the deposition in such a way as to cause the thinner regions to break up into separate globules. This method, however, has the disadvantage that impurities, which usually are found to concentrate at the edges, now become diffused into the interior and in addition the grain size of the whole specimen tends to be too coarse. The best method of eliminating the edge effect (other than hand trimming which is hardly applicable to small components) appears to be to etch the thinner parts away with acid.

Performance

The best time-constants achieved so far are about $2 \cdot 10^{-9}$ seconds. They have been measured in a flip-flop circuit by finding the minimum duration of pulse needed to switch from one state to the other. It is possible that switching times up to a factor two faster might be achieved.

Such times are no better than those attainable by other devices. The real advantages of the superconducting circuits are their miniaturization—it has been estimated that a store for 10^7 bits would occupy about a cubic foot—and their very small power dissipation. It also seems reasonable to assume that, once working in liquid helium, such circuits will be extremely stable and safe from deterioration since any chemical action is virtually excluded at very low temperatures.

But it must be emphasized that all low-temperature circuitry is still in the experimental state. Nobody has yet built a large operational circuit.

Other Circuits

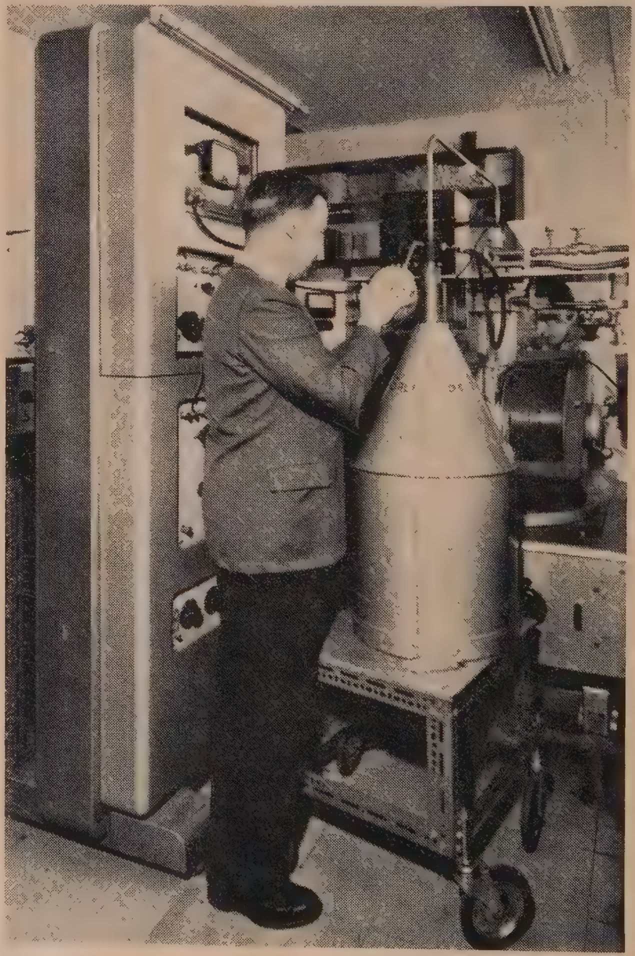
When cryotrons are to be driven from outside the low temperature environment, they present very low impedances to the external circuits. However, a number of conventional devices are known to function very well at very low temperatures—among them *p-n* junctions and tunnel diodes—so that no special matching problems are likely to be insuperable.

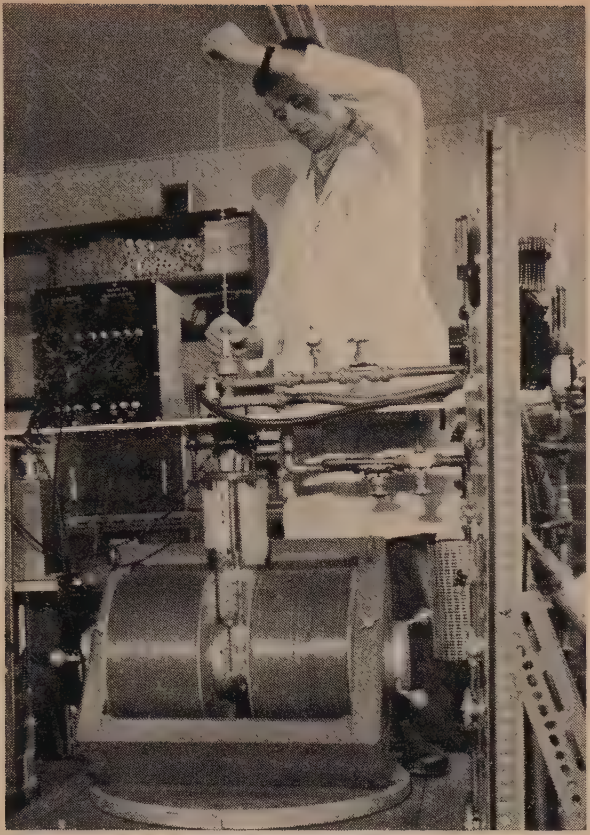
In this article, so far, the cryotron has been singled out for special description as it seems to be so flexible in application. Two other devices will now be briefly mentioned, one for its ingenuity and the other because of the possibilities it may open up.

For some years, storage circuits (Crowe cells particularly) have been constructed and extensively investigated which consisted, basically, of thin films of superconductor with small holes punched in them. Each hole could function as a two-state circuit, with a persistent electrical current circulating round it either clockwise or anti-clockwise. It was eventually realized, however, that there was no need to punch a hole in the metal—a resistive patch would fulfil the same function

Fig. 6. A typical set-up using liquid helium for research on the electrical and magnetic properties of materials. The liquid helium is in the metal transport vessel and is being transferred into a glass dewar vessel (whose top part can be seen projecting out of the electromagnet) where the experiment is to be done. The liquid is being forced by gas pressure, generated by squeezing the balloon, through the metal transfer tube.

(*Courtesy of Mullard Ltd.*)





(*Courtesy of Mullard Ltd.*)

Fig. 7. A continuation of the operation shown in Fig. 6. When the glass dewar is full of liquid helium, a test specimen can be lowered into it. The dewar vessel has been made with a narrow "tail" to allow a high magnetic field to act on the specimen inside.

of allowing a magnetic flux to penetrate the film. The new versions of this device—the continuous sheet memory—have the resistive patches produced by magnetic fields from circuits evaporated over the film.

Another device is a sort of tunnel diode, consisting of a sandwich of two superconductors (lead and aluminium) separated by a very thin insulating layer (aluminium oxide). As a result of the existence of different energy gaps in the two metals, the device can exhibit a small negative resistance in its current-voltage curve. It is too early to tell whether this will lead to useful applications.

Low Temperature Techniques

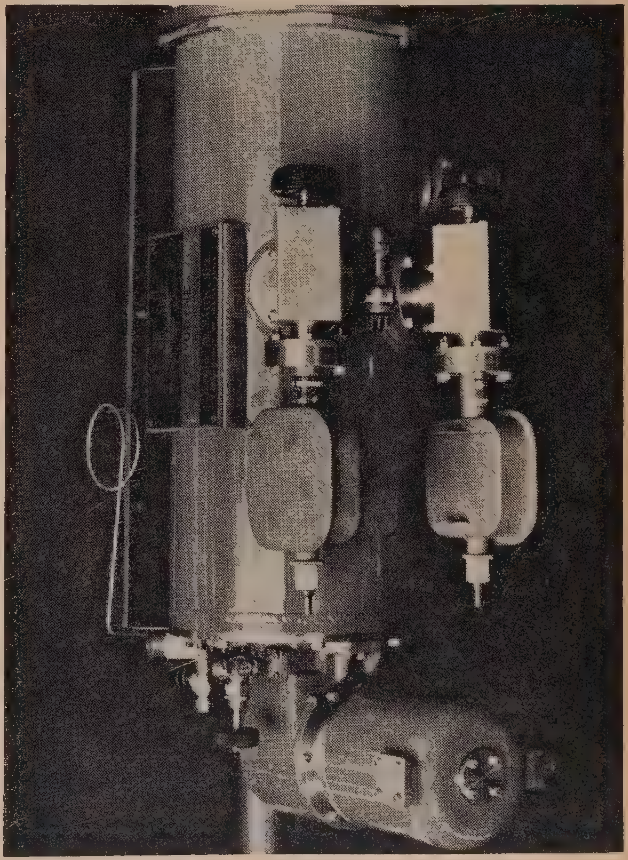
A very brief account of the low temperature aspects of these experiments will now be given.

First, for research purposes (where the specimens which have to be cooled are usually in the form of a small glass slide with leads attached to it) it is possible to lower the specimen into a bath of liquid helium contained in a metal or glass dewar (that is, a double-walled vacuum flask). The liquid helium dewar must itself, for protection, be immersed in another containing liquid air. In this country, it is possible to buy liquid helium from the British Oxygen Company; it can be easily transported in small dewars of 15 or 50 litre capacity, with little loss. The liquid cannot be simply poured out of the transport vessel into the experimental dewar, but must be forced over through a vacuum jacketed transfer tube. If experiments are to be carried out at temperatures below 4·2°K, the liquid helium must be pumped with a moderate sized vacuum pump, with arrangements to stabilize the pressure. Since all helium gas has to be imported from the U.S.A., the gas which boils off from the liquid helium has to be collected (usually in polythene gasbags), recompressed into cylinders and returned for subsequent reliquefaction. The auxiliary gas-handling gear costs not more than £300—£400.

On the assumption that it will eventually be necessary to keep a cubic foot of superconducting circuitry cold for extremely long periods while dissipating a few watts of power, the A. D. Little Company of Cambridge, Mass., has gone a long way towards designing a suitable refrigerator. The liquid helium never comes out of this machine, any more than the liquid ammonia emerges from a domestic refrigerator. Thermostated refrigerators which, on the average, produce liquid at just the right rate are highly economical to run. This is because all the cold contained in the evaporated vapour can be

Fig. 8. A small refrigerator—the "Cryodyne"—for keeping small electronic components cold indefinitely. It is completely automatic in operation. The actual volume refrigerated in this machine is a few cubic inches.

(*Courtesy of A. D. Little Inc.*)



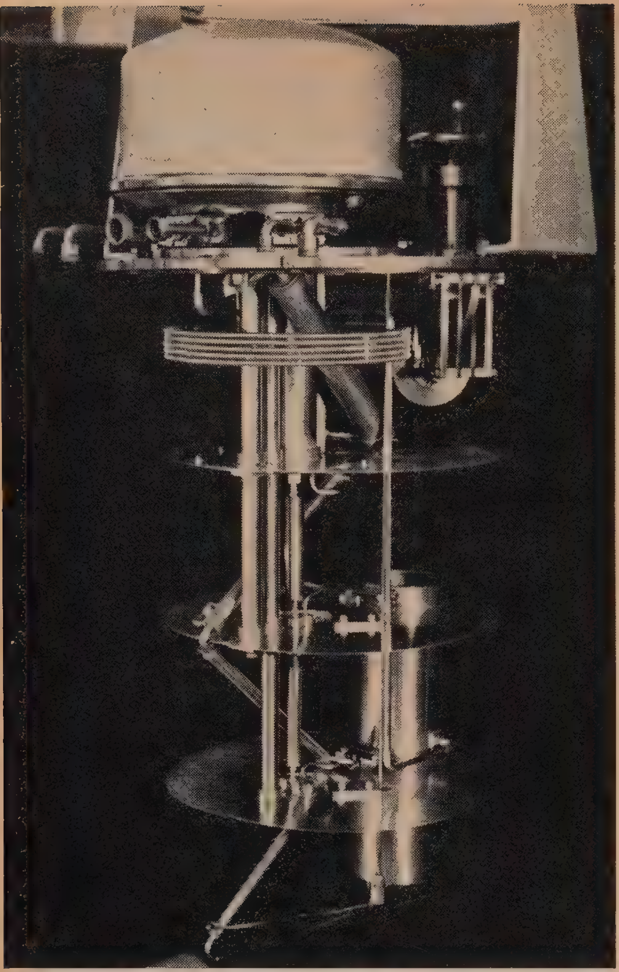


Fig. 9. The interior of an early version of a larger machine, suitable for refrigerating a larger volume, operating on the same principle as that in Fig. 8. The outer casing has been removed. The vertical tubes contain expansion engines which produce the cooling, the inclined tubes contain heat regenerators. The space available for components is at the bottom right.

(*Courtesy of A. D. Little Inc.*)

extracted by recirculating the gas through heat exchangers (whereas in an ordinary flask of boiling liquid this cold is simply wasted). The result is that a comparatively small machine will dissipate the required power. The second version of the helium refrigerator contained three expansion engines, with the gas circulating in a closed cycle. A year ago, it had certainly achieved 1,000 hours of continuous operation, with no attention being paid to it whatever. The cost of such a device (with full duplication of all working parts) is likely to be no greater than the cost of the kind of refrigerator which it is necessary nowadays to build into an ordinary large transistorized computer, to maintain it at room temperature. The running costs of the helium refrigerator are likely to be negligible.

Conclusions

As yet, superconducting circuitry is in its infancy. It is too early to say whether the advantages of small size and stability, combined with speeds as great as those of other devices, will prove decisive. Probably the most sober assessment is that of one of the leading research workers of one of the largest American corporations. He has said that probably in 5 or 10 years' time we will have a fairly clear idea of what the ultimate in computing techniques will be; and at that time it is fairly certain that superconducting devices will be on the short list.

NEW BOOK

Russian for English-speaking Students

By I. M. Pul'kina and E. B. Zakhava-Nekrasova
322 pp. Pergamon Press Ltd. Price 63s.

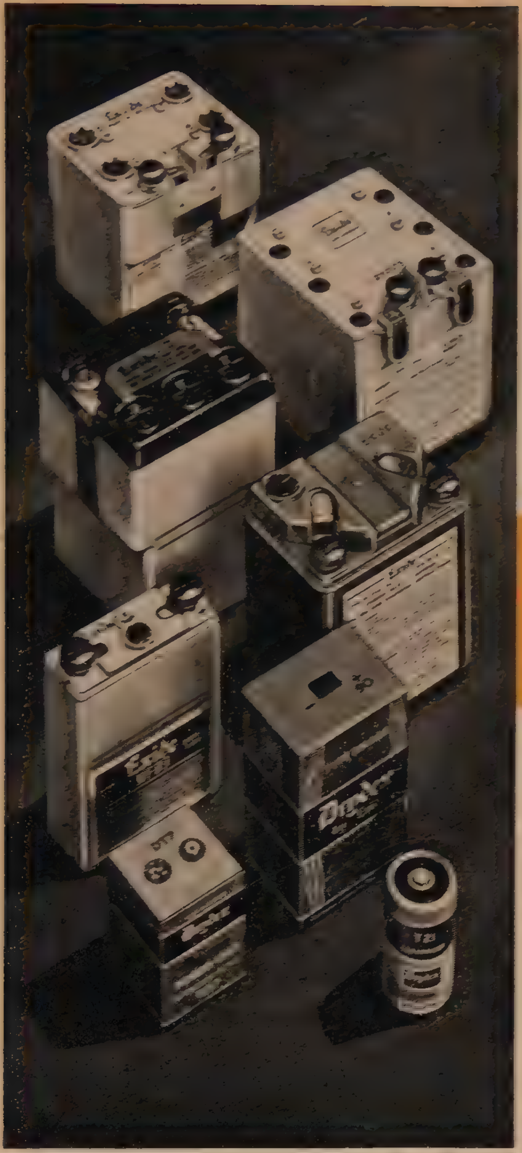
THIS BOOK is an English translation of a teaching grammar in use at Russian Universities for the instruction of foreign students receiving higher education in the U.S.S.R. and is, consequently, intended for those who already possess a good basic knowledge of the language.

The contents of this first volume (a second is in course of preparation) are set out in tutorial form and are devoted chiefly to an intensive examination of the Parts of Speech. Each is taken in turn as a subject of study and the student guided carefully through the maze of its forms and uses in the Russian language. The scope of the book is sufficiently wide to give it some of the character of a work of reference and, hence, should prove of special value in revisional work. The wide-ranging choice of material for study and the technique of presentation should, moreover, commend it to teachers anxious to relate the syllabus of work more closely to the needs of individual pupils, where standards of attainment vary.

Since the book is far removed from the category of primer, the authors have been able to dispense with some of the conventional forms of an ordinary grammar. With the study of grammar the main preoccupation throughout, set translations and vocabularies have been omitted and the large number of exercises provided are skilfully devised to test the student's understanding of the points studied and to encourage him towards free and confident expression in the language.

A special word of praise is due to the translator of the commentaries and explanations for having accomplished what must have been a difficult and exacting task, with such clarity and conciseness.

E. Doherty



DEVELOPMENTS IN THE FIELD OF BATTERIES*

The battery industry in this country is now some 70 or 80 years old. It is during the last two decades, however, that the most startling advances have been made. As in so many other fields, the aim has been to produce greater power for less volume or weight and, in some cases, to provide greater utility under difficult environmental conditions. This article discusses some of the developments which have taken place.

By Stanley Brown,
A.M.Brit.I.R.E., M.I.M.S.M.

Fig. 1. Lead-acid accumulators and Leclanche dry batteries for electronic purposes.
(Chloride Batteries Ltd.)

BROADLY SPEAKING, batteries may be divided into two main categories:

(a) those in which the electro-chemical actions are reversible so that the batteries are rechargeable. These are commonly known as secondary or storage batteries.

(b) those in which the chemical action is not fully reversible so that the batteries cannot be easily recharged. They are known as primary batteries.

In the field of secondary or rechargeable batteries, three of the systems evolved in the late nineteenth century are still with us in the form of the lead-acid cell, the nickel-alkaline cell and the silver-zinc cell.

Lead-acid System

In its commonest form today, the lead-acid system will be found embodied in the majority of batteries used on motor cars, aircraft and electrical vehicles (Fig. 1). The active materials involved are lead-dioxide for the positive plates, porous spongy lead for the negatives with an electrolyte of dilute sulphuric acid. The active materials are generally contained in grids or lattices of lead alloy and separation between the plates may consist of some highly porous form of inert and electrically insulating plastic material.

As might be expected with any system using materials of such great density, the trend of development has been to reduce the weight as much as possible; thus, the evolution of special grid alloys has enabled grids to be made much more resistant to corrosion and, hence, considerably lighter in section. The porosity of active materials which in turn leads to greater electrical capacity receives continuous attention. Generally, the step-by-step improvements are quite small and would perhaps tend to pass unnoticed in, for example, the

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*** With acknowledgments to The Chloride Electrical Storage Co. Ltd. and Chloride Batteries Ltd.**

operational field of car batteries. Nevertheless, the modern lead-acid car battery provides some 20% more power for the same weight than was the case even ten years ago.

It is convenient to consider the power/weight efficiency of batteries expressed in terms of watt-hours of output per lb. weight. Twenty years ago the lead-acid battery, in any form, had an efficiency of about 9 watt-hours per lb., while modern engine-starting and motive-power batteries have efficiencies up to about 14 watt-hours per lb. Small portable units for electronic purposes are in fact produced with efficiencies as high as 15 watt-hours per lb.

The main advantage of the lead-acid system is the relatively high electro-motive force which may be taken as approximately 2 V per cell. This, with the ready reversibility of the system giving a long and trouble free life, probably accounts for its very wide use in the portable battery field.

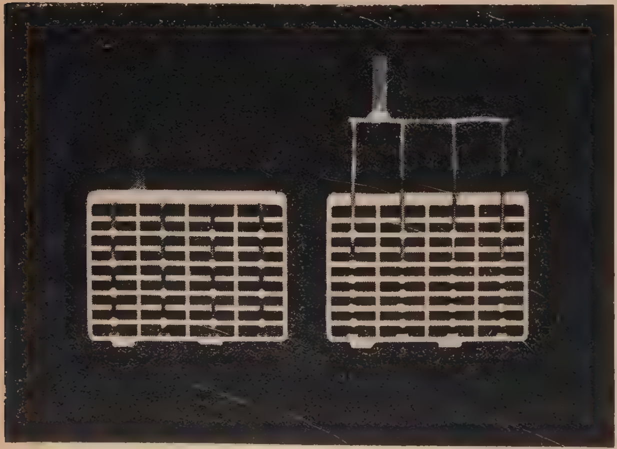
Plastic grids. In recent years a considerable amount of development work has been done on the substituting of plastic grids (Fig. 2) for the relatively heavy lead-alloy grids which are more generally used.

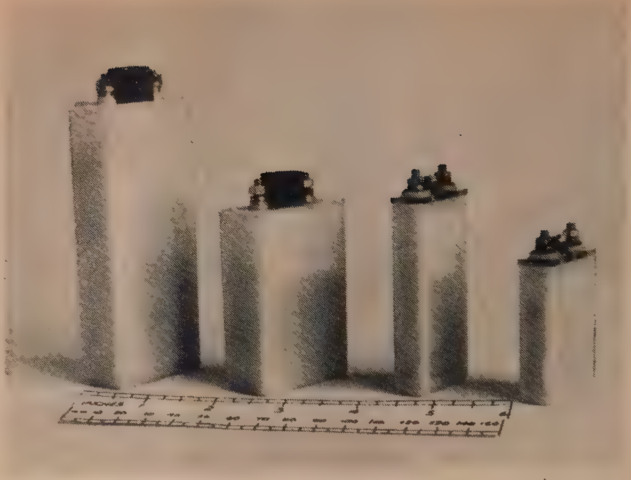
The plate grids are "dead" weight in the cell and any reduction which can be made in this weight—whilst still retaining adequate conductivity—is all to the good. These plastic grids are injection moulded and are fitted with lead-alloy inserts for current collection. A grid of this nature may well effect a 10% percentage reduction in battery weight. Another effect which is becoming increasingly important in electronic applications is that the rate of open circuit loss is considerably reduced. In other words, a battery employing a plastic grid of suitable design is able to stand idle for long periods without loss of capacity.

Today, it is becoming increasingly important to consider the behaviour of any battery system under differing atmospheric or environmental conditions. Thus, batteries are frequently required to operate at extremes of temperature or after long periods standing on open circuit. The effective capacity of the orthodox lead-acid battery is reduced by about 40% when operating at a temperature of −40°. Under normal ambient temperature conditions the open circuit loss may be designed to be as low as 1% of the capacity per month, but at +40°C. this open circuit loss will have been increased three to four times.

Fig. 2. A plastic grid showing the lead-alloy current collector wholly and partly inserted.

(*Chloride Batteries Ltd.*)





(*Alkaline Batteries Ltd.*)

Fig. 3. Miniature nickel-cadmium cells from 0·6 to 5·0 ampere-hours capacity at the 1 hour rate.

Dry-charged and self-priming batteries. The loss of capacity on open circuit before a battery goes into service is avoided by the development of batteries which are stored in dry condition and are brought into service by the addition of electrolyte only. A typical example is the normal lead-acid accumulator which is described as "fully dry-charged". This type of battery, which is now common in the military field, is simply brought into use by filling with electrolyte—no electrical charging being necessary. A variant of this principle was used in the Exide self-priming batteries designed for the operation of lifeboat radio equipment. These batteries had two compartment cells. The lower compartment housed the plates and the upper contained the electrolyte. The battery is rapidly brought into use simply by breaking a seal between the two compartments and permitting the electrolyte to enter the plate chamber. This priming process may be done either manually or by mechanical means.

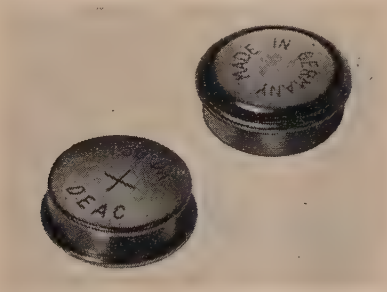
Fully dry-charged batteries may be designed to have a shelf life, even under the most adverse temperature conditions, in the order of five years or more, and even after the first discharge following priming they may continue to be used as orthodox rechargeable accumulators.

"Reserve" type batteries. The lead-lead-dioxide couple is also used to produce primary batteries of the "reserve" type which require filling with electrolyte to bring into immediate use. In these cases, the lead-dioxide of the positive plate no longer appears in a paste form but is electrically deposited onto a sheet of suitable metal, probably nickel. The lead-dioxide produced by electro deposition is dense and non-porous. The electrolyte may be a lead-dissolving acid such as perchloric or fluorboric and essentially this electrolyte must be added immediately before the battery is to be put into use. Batteries embodying this principle may be produced in any size from a few watts to several kilowatts. The build-up of voltage on priming with suitable electrolyte is extremely rapid even at temperatures as low as −40° and generally the capacity is unaffected by high temperatures up to about +40°C.

Pasted lead-dioxide positive plates are also used against negative plates of zinc or cadmium to produce primary batteries of the "reserve" type which were used in the earliest ballistic experiments with guided projectiles. In this case the electrolyte is basically sulphuric acid and is added immediately before operation. This principle enables the batteries to be built into the test vehicle and brought into use by priming the electrolyte through an external gland. Similar units are produced for the powering of radio and radar sondes.

Nickel-cadmium Alkaline Cells

With this type of reversible cell (Fig. 3), the positive material is basically nickel hydrate and the negative material consists of cadmium and iron oxides. The electrolyte is mainly potassium hydroxide and, unlike the lead-acid accumulator, this electrolyte takes no part in the chemical action of the cell. There is no local action between the electrolyte and the electrodes and, on open circuit, this type of battery is almost completely inert. The cell has an average discharge voltage of 1·2 V, and when compared with the lead-acid battery an increased number of cells is required for a given overall battery voltage. In the normal construction the efficiencies expressed in watt-hours per lb. are not appreciably different from that obtained from lead-acid batteries, the lower weight per cell being countered by the increased number of cells required. Of particular interest to the electronics field, however, is the development of the sintered-plate battery. Here, the plate consists of a grid, or matrix of sintered nickel, and the positive and negative active materials are contained in the fine pores of the sintered material. This form of construction enables the plates to be made extremely thin so that each cell may contain a large number of thin plates with a considerable reduction in the internal resistance of the unit. This type of construction is valuable where an exceptionally high current demand is required for a short period while the saving in space may be considerable.



(*G. A. Stanley Palmer Ltd.*)

Fig. 4. DEAC button-type cell of 150 milliampere-hours capacity. Diameter 25 mm. Height 6·6 mm.

Mechanically the sintered electrode system may be assembled in two ways, to produce either an open type cell or a cell which is, to all intents and purposes, fully sealed. In the permanently-sealed category the construction lends itself to the production of very small units and the "button" type cell is a typical instance. A DEAC "button" type unit (Fig. 4) having a capacity of 50 milliampere hours is about 10 mm in diameter and 4 mm high. Larger capacity cells are made in a tubular form of construction with one contact to the outer steel case and the other to a centrally-mounted type electrode rather like an ordinary torch cell. Still larger capacities are produced in a rectangular shape.

These small units are probably most effectively used in equipment which can also embody some form of built-in charging circuit.

The recharging characteristics of small hermetically-sealed cells are sufficiently critical to demand every care in the recharging process. This is quite easy to achieve when the charging circuit is specifically developed to suit the requirements of the cells. In this way, one arrives at a highly desirable feature in any battery-operated circuit—that of the maintenance-free battery. Because the unit is hermetically sealed, there is no loss of electrolyte, so that topping-up is not only unnecessary but generally impossible, while the use of a correctly designed associated charger removes most of the doubts about recharging.

Silver-zinc Accumulator

Here again, we are dealing with an electro-chemical couple which goes right back to the days of Volta. The electrodes are silver-oxide and zinc with an electrolyte of caustic potash. The system may be used either as a primary cell or as a rechargeable battery. Over the years, a considerable amount of effort has been applied by many authorities all over the world to improve the rechargeable characteristics of this system. The advantage of the silver-oxide-zinc couple is best expressed in terms of output per unit weight. This is extremely great and may well be as much as four or five times as much as that obtainable from either the lead-acid or the nickel-cadmium battery. At the moment, the units are mostly used in small electronic applications, but if the durability and reliability of the system could be improved the scope for its use would be considerably wider. At the moment, however, silver-oxide-zinc cells offer the greatest advantages where they can be used as primary batteries or as rechargeable units where only a relatively small number of charge and discharge cycles are required. Using, as they do, a semi-precious metal the cost must necessarily be high.

Primary Batteries

Undoubtedly, the most ubiquitous battery in this field is built on the Leclanche principle. Fundamentally

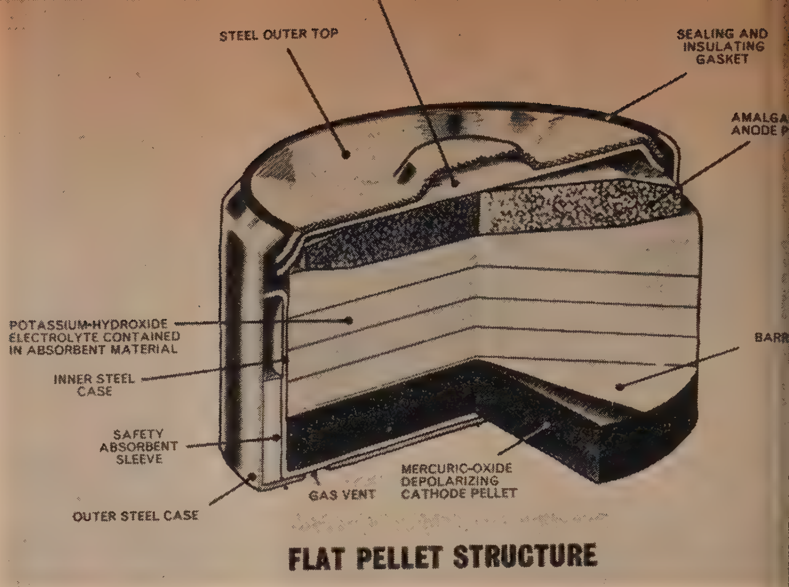

STEEL OUTER TOP
SEALING AND INSULATING GASKET
AMALGA
ANODE P
POTASSIUM-HYDROXIDE ELECTROLYTE CONTAINED IN ABSORBENT MATERIAL
BARR
INNER STEEL CASE
SAFETY ABSORBENT SLEEVE
MERCURIC-OXIDE DEPOLARIZING CATHODE PELLET
GAS VENT
OUTER STEEL CASE
FLAT PELLET STRUCTURE

Fig. 5. Mallory Type RM-4R mercury cell of 3400 milliampere hours capacity.
(*Mallory Batteries Ltd.*)

the Leclanche cell consists of a zinc and carbon electrode with an electrolyte of ammonium chloride. In any primary battery one of the electrodes is always sacrificial or is burnt up by the action of the cell. In this case it is the zinc and the carbon is not truly an electrode but purely a convenient current collector. Cells of this type would be subject to hydrogen polarisation and, in practice, the carbon electrode is surrounded by a compound containing manganese dioxide which acts as a depolariser. In the so-called dry cells the electrolyte is made up into a wet paste or jelly in order that it may be immobilized in the cell.

The most familiar method of construction is to use the zinc electrode as the cell container and the majority of cells of either cylindrical or rectangular shape are thus made. An alternative form of construction, with a far better space factor, is the layer-built method. Fundamentally, this implies the use of a bi-polar or duplex electrode such as a piece of zinc which has been coated on one side with a thin layer of impermeable but highly conductive carbon. The carbon electrode and the depolariser are usually moulded into a flat slab which, together with the separator, is soaked in electrolyte. These units are assembled one in contact with the other following the familiar Voltaic pile principle, and thus the necessity for intercell connectors is avoided.

The Leclanche system produces a terminal voltage of 1·5 V per cell and the geometry or the chemistry of the unit may be varied to suit different types of operating conditions. In the main, however, dry batteries are intended primarily for intermittent service and most of them are tested against an intermittent discharge. In this country, it is usual to rate the capacity when discharging into a fixed resistance load for periods of from 2—4 hours per day. The Leclanche type of unit is considerably affected by temperature, the performance being considerably reduced at temperatures of −15°C. The behaviour of the cells under open-circuit conditions—in other words the "shelf" life—is also affected by temperature with low temperatures extending and high temperatures reducing this characteristic. Improvements in the shelf-life characteristics of cylindrical cells over the past twenty years have been quite remarkable.

The cylindrical types of cell may be used for relatively high discharge rates, while at rates up to 20 mA or so and where space is important the layer-built unit becomes particularly attractive.

Mercury cells. In the electronic field, where miniaturization is always so important, another electric-chemical system is frequently used (Fig. 5). This system, embodying the use of electrodes of mercuric oxide and zinc in an electrolyte of caustic potash, was developed during the last war by Samuel Ruben and the Mallory Company in America.

The system lends itself to the production of very small units which are almost "hermetically" sealed and the familiar "button" type primary cells generally embody this principle. The nominal voltage is approximately 1·34 V per cell, a good average working voltage being about 1·2 V per cell.

Mercury cells can be economically used at rates as high as the 10-hour discharge rate and the cells have good storage characteristics under tropical conditions. Unfortunately, the performance is badly affected by low temperatures, a sharp decline being noticed at temperatures below about 5°C. The construction is extremely robust and although occasionally leakage of electrolyte may occur it is only after prolonged storage under fairly high temperature conditions.

Current Trends

Considerable attention is now being given to the utilization of solar energy as a source of power. Attention is being focused on this source because of the interest in the development of satellites both for exploratory and communication projects. It has been estimated that with the sun directly overhead the solar energy falling on the earth is equivalent to about 1 kW to one square yard of surface. Even with conversion efficiencies as low as 8—10% the use of the solar source thus becomes attractive.

Modern developments in the solar cell stem from the use of semiconductor materials, the most important probably being silicon. Originally developed in the

U.S.A. by the Bell Telephone Laboratories, they are being produced, at least experimentally, by a number of British organizations. The individual solar cell produces the maximum amount of power at approximately 0·3 V per cell, the power output generally being in the order of about 10 W/ft^2.

While the cells can be used directly, they are probably more efficiently used as charging sources for orthodox secondary batteries and a number of existing satellites have in fact been so equipped. Rather more earth-bound projects are concerned with the operation of navigational lights or warning devices.

Another development stemming from the use of semiconductor materials is in the field of thermo-electric generators. Here one is looking for the direct conversion of heat into electrical energy on the familiar principle of maintaining junctions of dissimilar metals at widely different temperatures. In the satellite field as much thought is being given to the utilization of the sun's heat in this way as to the utilization of the sun's light in the solar cell. Where the sun's heat is involved, collector and radiator assemblies form a large part of the thermo-electric cell construction but, of course, any other conventional form of heat can in fact be used.

Probably the most exciting field of electro-chemical research today, however, lies in the application of the fuel cell principle. This development work is not restricted to orthodox battery manufacturers and, in fact, almost every organization interested in the production of a suitable fuel is becoming interested in the development of fuel cells.

Obviously the attraction of being able to convert fuel into electricity without going through the intervening stages of mechanical generation is very great. In the fuel cell electrical energy is produced by the oxidization of the fuel in contact with suitable electrodes which, however, generally take no part in the chemical action of the cell. The oxygen may be supplied as a pure gas or derived from air and the fuels range from hydrogen in the case of Bacon's hydrox cell through a large number of other gaseous or liquid fuels. Alternatively, an electrode of sodium or zinc for example may be the fuel.

Obviously, the field of batteries still contains a tremendous development potential in spite of the fact that over 120 years has elapsed since the first storage battery and, indeed, the first fuel cell was, evolved. Of that long period the last 20 years has been particularly rich in development, inventiveness and the desire to tailor a product to the need.

ULTRA-VIOLET TELEVISION CAMERA TUBE

THE direct observation of fundamental processes in living cells has been the aim of biologists for many years. This has now been brought a step nearer by E.M.I. Electronics Ltd. who have developed an ultra-violet-sensitive vidicon television camera tube. Experiments in ultra-violet microscopy have recently been carried out by Dr. R. Barer, at the Department of Human Anatomy, Oxford University, using an E.M.I. closed-circuit television camera fitted with this new tube.

The experiments were described in a paper read by Mr. J. Wardley of the E.M.I. Research Laboratories at the "Symposium on Photo-electronic Image Devices as Aids to Scientific Observation", at the Imperial College of Technology, South Kensington, on 6th September.

Normally, the method of using an ultra-violet microscope—which can observe details in cells of animals or plants not visible to the human eye—is to take a large number of photographs for different settings of the controls, in order to ensure that some of them will be in focus. Also, high-intensity ultra-violet radiation quickly kills the cells, and another disadvantage is that it takes time to develop and print the photographs—some of which may be so much out of focus as to be unusable.

The tube developed by E.M.I., however, is so sensitive that the amount of ultra-violet radiation can be reduced to a level which does not kill the cells for a considerable time. The observation is immediate and continuous, and a specimen can be examined for interesting features in breadth, width and depth by moving the specimen stage and by focusing the microscope through the depth of the specimen as easily as in ordinary light microscopy. It is thus possible to inspect a large number of specimens in one hour where it would otherwise have taken several months.

During the experiments a variety of living cell preparations were examined, including free swimming chromosomes and live sperms of mice, frogs, and other small creatures, swimming through the field of view. Good pictures on the television screen showed the differentiation of various cell features due to absorption of the ultra-violet by nucleic acid and protein molecules.

Observation of cell division on a television microscope is a very stringent test as the cells are very sensitive to ultra-violet radiation. If there is sufficient sensitivity in the tube, the ultra-violet intensity can be kept low enough for the cell division to be observed. The new ultra-violet tube is said to have greater sensitivity than any other available, and it also has higher gamma—giving enhanced contrast—and short lag. It is hoped to be able to observe actual cell division with the aid of the new tube.

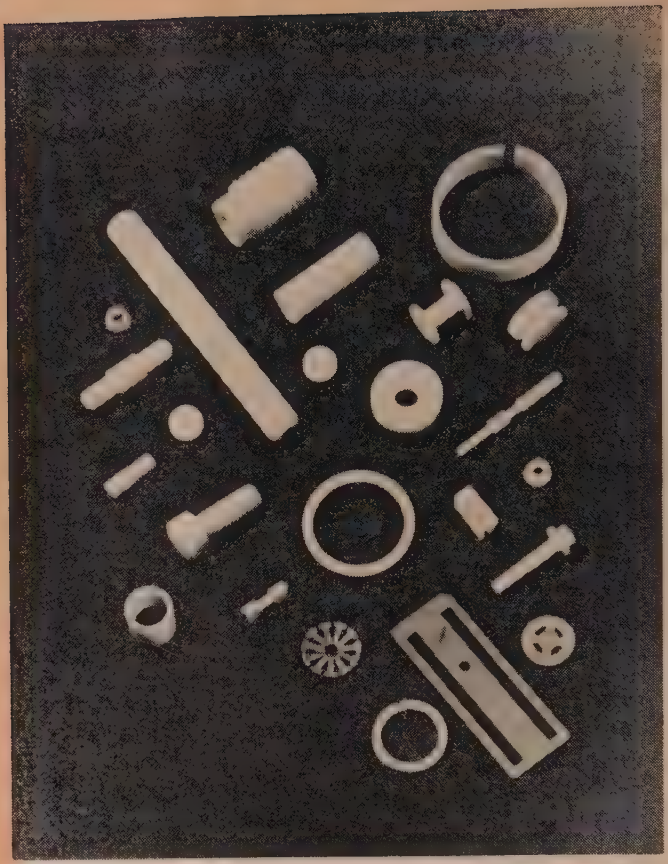
There is reason to believe that the cost of an ultra-violet microscope installation can be considerably reduced by the use of a closed-circuit television camera equipped with this tube.

It must be emphasised, however, that this tube is still at the experimental stage and will not be commercially available in the immediate future.

MODERN
DEVELOPMENTS
IN

Industrial Plastics for the Electronics Industry

BY P. D. MITCHELL
Polypenco Ltd.


Typical components machined from extruded plastics including Nylon 66, p.t.f.e. and Q.200.5 materials.

Introduction

DURING the last ten or fifteen years very considerable advances have been made in the plastics industry, both in the development of new materials and in the application of such materials to the individual needs of the design and development engineer. Nowadays it is true to say that the availability and background knowledge of plastic manufacturers and fabricators is sufficient to ensure that any design engineer may receive sound advice on a potential product from the material choice and manufacturing viewpoints. The tremendous growth of the plastics industry during this time has naturally led to specialization and diversification of effort into certain channels.

Probably the most well-known plastic materials in the Radio and Electronics Industries are the thermo-setting plastics which have been used for many years and will, of course, continue to be used widely in the future. However, during and since the last war the rapid growth of the Electronics Industry, with a consequent increase in the use of electro-mechanical devices has led to differing requirements for insulating materials having in addition good mechanical properties.

These new design problems, coupled with an ever-increasing tendency towards miniaturization of components, has placed great emphasis on the development of thermo-plastic materials and their uses in the electronics industry.

Probably the most widely known materials of this nature are the polytetrafluoroethylene resins and the family of nylon polymers. New developments have arisen from these basic materials and it is hoped to sum up the current availability of these industrial plastics during the course of this article.

The Nylons

Nylon is a generic term applied to a family of thermoplastic materials known technically as polyamides. Whilst many applications could successfully utilize many grades of nylon, it is not until design improvements are made which call for more stringent control of properties that it becomes necessary to consider individual grades of nylon and their own specific properties. To avoid subsequent problems, therefore, it is essential to realize that the properties of nylons vary considerably from one to another. This choice of the correct grade of nylon for a particular purpose may be further widened by consideration of the "filled" nylons—or nylons with certain additives designed to improve specific properties.

To return to the unfilled grades of nylon, those generally used in the British Radio and Electronics industries are the following: Nylon 66, Nylon 610, Nylon 6 and Nylon 11. The first two grades mentioned probably combine the best combinations of physical strength and electrical insulating properties, depending upon application requirements. Nylon 6 is characterized as a general purpose mechanical grade of nylon having a rather high moisture absorption but excellent impact strength, whilst Nylon 11 has a good electrical insulating properties, but rather low mechanical strength.

Nylon Type 66 is the most widely used general purpose grade of nylon, manufactured in Britain by the Plastics Division of Imperial Chemical Industries Ltd., and is often known by the I.C.I. trade name "Maranyl A.100". The properties of this material, together with Nylon Type 610 (I.C.I. "Maranyl B.100") may be studied from the Property Value Chart on page 842.

Generally speaking, Nylon 66 is the hardest and strongest unfilled grade of nylon available and finds the majority of its applications where high mechanical strength, coupled with reasonable electrical insulating properties are required. It can be best described as a "horn-like" material which is resilient, tough, with a low frictional coefficient and a hardness similar to white metals. All nylons are resistant to higher temperatures than the majority of other plastics, Nylon 66 having a heat distortion temperature at 264 lb/in.^{2} of 93°C and being characterized by a sharp melting point at 265°C.

The material has a low dielectric constant and a relatively high dielectric strength which enables parts to resist high voltages at commercial power frequencies. It is not usually suitable for high-frequency, low-loss applications. Relatively high volume and surface resistivities can be maintained even after prolonged exposure at 100% relative humidity, and the material is inherently sound-dampening and thus finds many uses where mechanical vibration and noise levels must be reduced, such as in tape-recorders and cine-projectors.

Nylon 66 is used for rubbing blocks, bearings, coil formers, relay spacing studs, insulating washers, electrode insulating shields and general-purpose insulation. A good example of the latter use is found in the wide range of nylon screws available today and finding widespread general use in the electronics and electrical industry. Such screws are also self-locking and do not loosen when subjected to vibration. A further interesting property is the fact that the material is non-gassing under vacuum. This property has already led to the choice of Nylon 66 for insulating spacers in the atomic energy field.

The material may be injection moulded where large quantity production is required of a relatively complicated item. For simpler, regular shapes and smaller quantities of, say, less than 10,000 off, Nylon 66 extrusions may be machined readily on standard metal working equipment. The material should be machined in a similar fashion to brass whilst using a coolant.

An extremely wide range of extrusions is available in Britain which include round rod, hexagonal and square bar, tubes, strip, sheet, disks and thin-wall tubing. Special formulations are available which are compounded for sunlight resistance, heat resistance and are colour pigmented. In this latter connection it is interesting to note that Nylon 66 may be dip-dyed in a water-soluble, fast dye to give a cheap, effective form of permanent colour coding for items where this form of identification is necessary.

Nylon 610. This material is not as widely used in the electronics field as might be supposed, owing to its much higher price compared to Nylon 66. However, the dielectric strength of 470 V/mil. is extremely high for a polyamide material and moisture absorption is greatly reduced compared to Nylon 66 thus giving greater dimensional stability under conditions of widely varying humidity. Nylon 610 has a lower heat distortion temperature than Nylon 66, lower modulus of elasticity and slightly higher thermal expansion coefficient. Applications are similar—in particular for insulators and similar components demanding the general characteristics of nylon plus high dielectric strength for premium insulating properties.

In similar fashion to Nylon 66, Nylon 610 is available as a powder for injection moulding and as a wide range of semi-finished standard shapes for subsequent machining.

MC. Nylon 901. This is an entirely new grade of nylon manufactured by Polypenco Ltd. in Britain. The material is characterized by good electrical insulating properties, average moisture absorption, high mechanical strength and an extremely high heat distortion temperature. This latter property is the highest of any of the unfilled nylons and is nearly 40°C greater than that of Nylon 66.

MC. Nylon 901 is not available as a moulding powder, but is offered for particularly large applications where internal stress build-up has precluded the production of massive standard shapes in other grades of nylon.

Whilst such massive shapes could appear to be of little use to the Radio and Electronic Components industry, it is interesting to note that several applications have already occurred since the announcement of this material. In each case, the good electrical insulating properties plus the high heat distortion temperature were the reasons for choosing this material in preference to any other grade of nylon.

Filled nylons. All polyamide materials are somewhat difficult to extrude or mould owing to their inherently high melting points and sharp softening points. Addition of large quantities of fillers to these materials tends to cause an increase in cost of manufacture and high scrap rates. Hence, the quantity of filler added must be related to the economics of manufacture on the one hand and physical benefits on the other. Usually, the increase of a filler in nylons designed to increase tensile strength or reduce friction will result in a loss in impact strength and it is, therefore, preferable to consider the filler which gives the maximum benefit to certain properties for the minimum amount used.

Fillers such as carbon black added to nylons in small quantities increase the materials' resistance to ultra-violet light degradation very considerably. Little loss of other properties is experienced in this case or in the case of the addition of heat stabilizers to prevent oxidation by hot air or hydrolysis by hot water reaction. These are comparatively specialized applications of fillers to cover specific limitations inherent in the material. Other uses of fillers are designed to increase a number of physical properties with the minimum sacrifice of electrical and physical properties. The two important fillers are molybdenum disulphide and graphite. Both materials are added to many grades of nylon to increase tensile strength and modulus of elasticity and to reduce the coefficient of friction of the nylon under consideration. It has been found, however, that whilst the coefficient of friction of the nylon is undoubtedly reduced slightly by these additives, the secondary benefits obtained by the correct blending of nylons and fillers have proved to be of more importance. These include increase in tensile strength and modulus of elasticity, large increases in heat distortion temperature and increased hardness with reduction in coefficient of thermal expansion.

In the writer's opinion, there is little point in taking a softer grade of nylon, adding a filler, thereby attempting to increase its mechanical properties to those of an already existing unfilled grade. It seems logical to take the hardest standard grade of nylon, namely Nylon 66, and consider the effects of additives to this material alone.

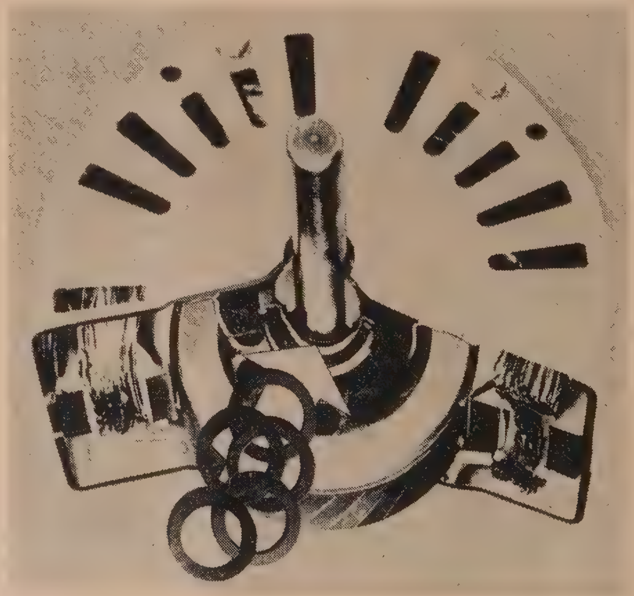
Nylon 66 plus graphite has been marketed for some years and has offered, in effect, a harder grade with lower coefficient of friction but with greatly reduced impact strength. During recent years it has been found that much smaller quantities of molybdenum disulphide (M_0S_2) added to Nylon 66 achieves even better physical properties than in the case of graphite.

One of the better known combinations of Nylon 66 and M_0S_2 is "Nylatron GS" (Polypenco Ltd.). The physical properties of this material are shown in the Property Value Chart and may be compared with Nylon 66, etc. It is particularly interesting to note the reduction of about 40% in thermal expansion plus *increased* hardness, tensile strength, modulus of elasticity and heat distortion temperature. A reduction in coefficient of friction is also achieved and both dielectric strength and dielectric constant are little affected. It is believed that these physical properties accrue from the fact that the addition of M_0S_2 to Nylon 66 promotes crystal formation. It is the level of crystallinity in any grade of nylon allied to its distribution in the finished piece which is of prime importance in determining the final performance of that piece in its environmental application. A typical application of "Nylatron GS" is seen in Fig. 1.

Polytetrafluoroethylene. This material is marketed in Britain under the trade names "Fluon" (Imperial Chemical Industries Ltd.—Plastics Division) and "Teflon" (Du Pont (U.K.) Ltd.) and is generally known as p.t.f.e. or Fluorocarbon t.f.e. P.t.f.e. is white or grey in colour, is soft when compared with the nylons and has a characteristic "waxy", low frictional surface, readily recognized by touch.

P.t.f.e., as may be seen from the Property Value Chart possesses outstanding electrical properties coupled with unique complete chemical resistance. The material is inert and non-toxic and has an operating temperature range of −250 to +260°C. This is the widest temperature range of any known plastic material and in addition

Fig. 1. "Nylatron GS" thrust washers used in a small electric motor.



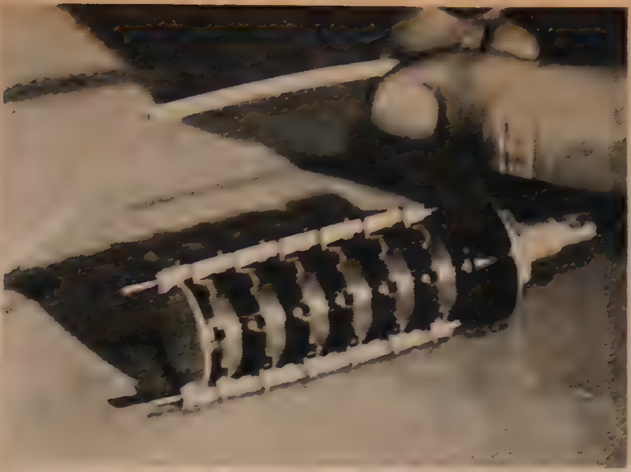


Fig. 2. "Fluon" thin-wall sleeving.

it is unaffected by sunlight, weathering and does not absorb moisture. The power factor is less than 0·0005 over the entire frequency range, the dielectric constant of 2·0 is also stable over this range, whilst the short time dielectric strength is high and the volume resistivity is greater than $10^{15}\,\Omega$ cm. after prolonged soaking in water.

P.t.f.e. is available in a very wide range of extruded shapes including rod, tube, tape, sheet, cored bar and coloured sleeving. The material cannot be injection moulded and is, therefore, generally fabricated into component parts by machining from semi-finished shapes. It can be compression moulded but this technique is not as widely used as machining owing to the difficulties in producing close tolerance, cleanly finished components by this method. Undoubtedly, the cost of p.t.f.e. has limited its widespread use in the electrical industry but it is significant to note that raw material costs have been reduced from £5 per lb. to 30s. per lb., over the last few years. Consequently, the use of p.t.f.e. in the electrical and chemical industries is now increasing rapidly.

Major uses include wire and cable insulation, coil and slot insulation for motors, generators and transformers, condenser dielectrics, spacers and terminal blocks, stand-off and lead-through insulators, co-axial connector insulation, seals, packings and instrument bearings. A typical application of p.t.f.e. thin-wall sleeving is shown in Fig. 2.

Unfortunately, this particular material, whilst eminently suitable for sleeving, stand-off insulators, tape manufacture and other "semi-flexible" applications, is a relatively soft material with high elongation but low tensile strength and hence, a low modulus of elasticity. In addition, it exhibits a tendency to cold flow under comparatively light loads and has, therefore, not been used for the many potential bearing and insulation applications which its extremely low frictional coefficient and dielectric properties would suggest.

This drawback has led to the development of a variety of filled p.t.f.e. compounds with the express purpose of increasing the stability and load bearing capacity of pure p.t.f.e. with as little sacrifice as possible of the already outstanding electrical, chemical and thermal properties of the virgin material. Many additives such as glass-fibre, molybdenum disulphide, graphite, asbestos and similar materials are in use either in individual or compounded form.

Polypenco Ltd. has developed a p.t.f.e.-based resin known as "Fluorosint". This material has an extremely low coefficient of thermal expansion (similar to that of aluminium) and excellent resistance to thermal shock. (See Figs. 3 and 4). Other physical properties may be seen from the Property Value Chart. "Fluorosint" will operate as a bearing up to p.v. (pressure-velocity) ratings

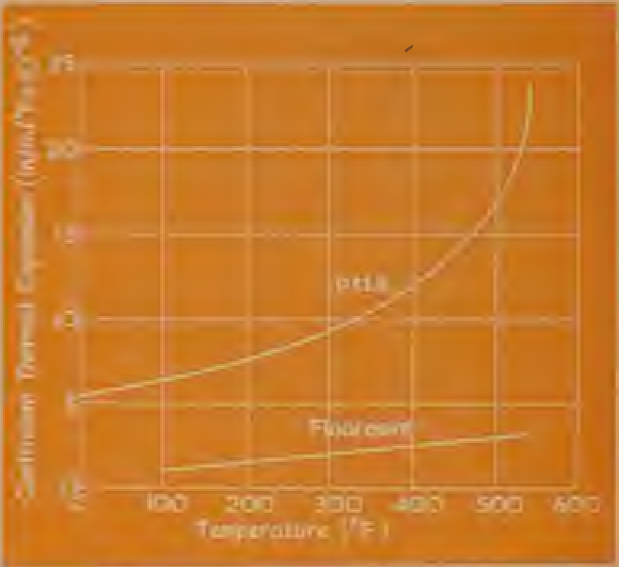
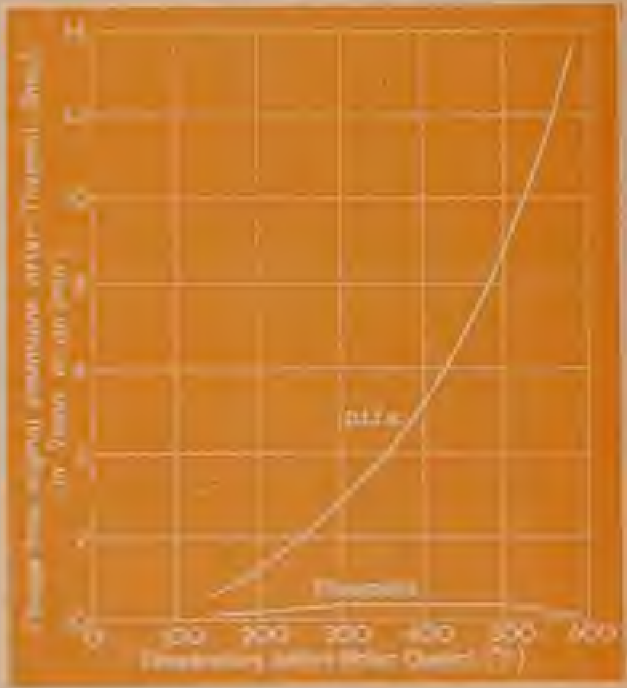


Fig. 3. Linear coefficient of thermal expansion versus temperature.

Fig. 4. Change of dimensions on thermal shock.



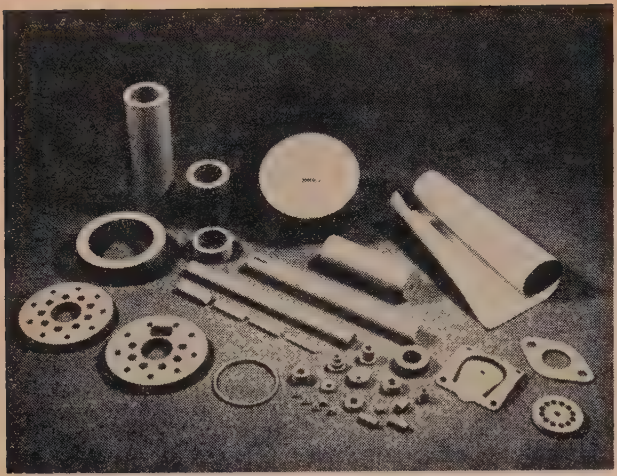


Fig. 5. Typical selection of "Fluorosint" semi-finished shapes—moulded and machined parts.

of 15,000 with extremely low wear rates and at temperatures up to 250°C without distortion or flow under load. Apart from a slight increase in dielectric constant the electrical properties are virtually the same as those of unfilled p.t.f.e. "Fluorosint" semi-finished shapes are available in rods, tubes and tape and may be readily machined to form component parts. The most outstanding feature of this material however is its ability to be compression moulded to extremely close tolerances at production rates of up to 1000 per hour. Components up to 4 in.^{2} cross-sectional area by 2½ in. long may be produced by a modified powder metallurgy technique without subsequent machining and with excellent surface finish. A typical selection of "Fluorosint" semi-finished shapes, machined and moulded parts is illustrated in Fig. 5. It is expected that components produced by this technique will show important savings in scrap and increase still further the uses of p.t.f.e. and its compounds in the electronics and radio industries. In several cases "Fluorosint" has achieved success in such applications as radar equipment where p.t.f.e. alone was incapable of holding the tolerances necessary over the desired working temperature range.

New Developments

Although several new developments have been covered in the preceding text it is felt that these are logical improvements on existing materials. The purpose of the remainder of this article is to describe new developments which either involve completely new materials or have been developed from existing forms to such an extent as to open up new fields of application in the radio, electronics and electro-mechanical industries.

Q.200.5. (Polypenco Ltd.). This material is a thermosetting plastic in contrast to those previously described which are thermo-plastic resins and (with the exception of p.t.f.e. and its compounds) are capable of being melted and re-processed after suitable treatment. In the case of a thermo-setting plastic, a chemical change takes place during manufacture which renders the material incapable of being re-processed or re-melted in the true sense. An epoxy resin may be similarly classified.

Q.200.5 is a rigid, transparent insulating material made by a chemical cross-linking process with polystyrene as the basic material. It is available in rod and plate form and may be readily machined by orthodox metal-working techniques and equipment. The excellent electrical properties and high temperature resistance may be seen from the chart. It should be mentioned that whilst the dielectric strength of "Q.200.5" is superior to nylon and p.t.f.e., its volume and surface resistivity is no less than 10 times higher than the latter materials. The material is rigid, has extremely low moisture absorption and has excellent resistance to deformation under load.

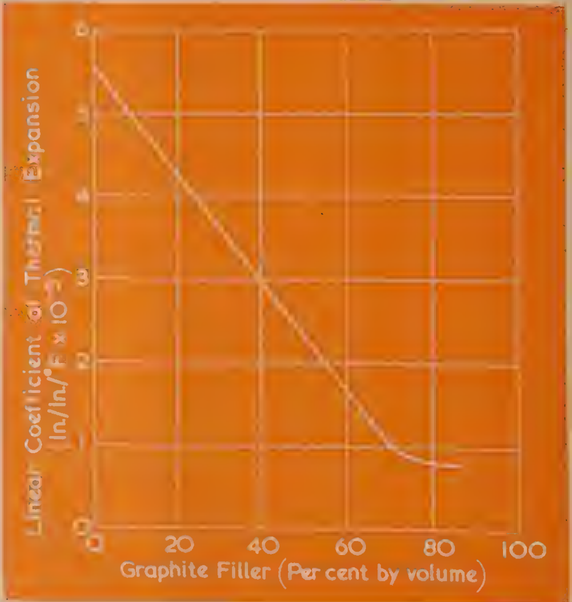
It is at present being utilized by several major electronic manufacturers for insulators, particularly at ultra-high frequencies.

K-51 Penton. This material is a new chemically inert thermoplastic developed by the Hercules Powder Company and marketed in Britain by Hercules as an injection moulding powder and by Polypenco Ltd. in the form of extruded semi-finished shapes. Penton is a chlorinated polyether resin which is essentially characterized by extremely good chemical resistance, second only to that of p.t.f.e. Whilst the majority of applications are likely to be found in the chemical industry its electrical properties are interesting in that loss factors are low over a wide range of frequencies. Dielectric strength is approximately 400 V/mil., and moisture absorption is nil. Components requiring good chemical resistance combined with good electrical properties should be considered in relation to this material.

Sintered Nylons

As previously mentioned in this article, the development of filled nylons has been retarded by the difficulty in processing by orthodox methods when large pro-

Fig. 6. Thermal expansion of "Nylasint" parts with varying graphite content.



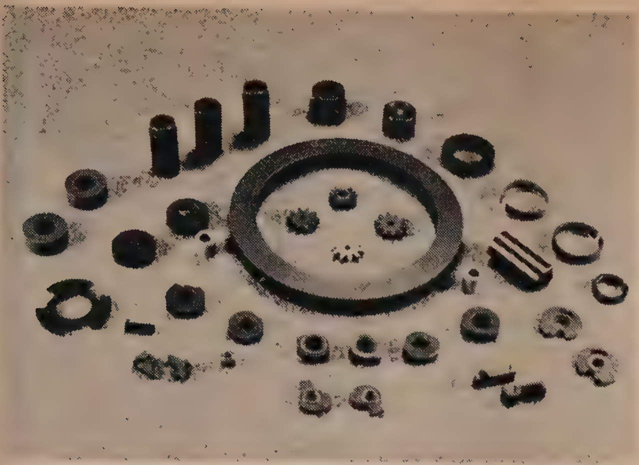


Fig. 7. Typical "Nylasint" pressed and sintered components.

portions of fillers are added. As the result of several years continuous research work, the Polymer Corporation of Pennsylvania, the pioneers of nylon and p.t.f.e. extrusions in the U.S.A., have overcome this problem by an important new development in polymer processing techniques. The results of these efforts in the form of "Nylasint" sintered nylon components are now available through the manufacturing facilities of Polypenco Ltd.

Essentially, the production development of finely-divided nylon powders may be compared to the techniques of powder metallurgical production of pressed and sintered metal components, and it is now possible to produce a sintered nylon component consisting of a Type 66 Nylon with, say, 80% graphite or 30% molybdenum disulphide content. These parts are produced at high speed to very close tolerances with high crystallinity, complete uniformity of properties throughout the piece and no residual internal stresses. Whilst several standard grades of these materials are available—namely "Nylasint" M-4, 6-G, and 64-HV (see chart) it may be readily seen from Fig. 6 that the properties of a required item may be virtually "tailored" to the applicational requirements. Physical limitations in size are similar to those already stated for "Fluorosint" pressed and sintered parts, whilst normal design limitations applicable to powdered metal part production would apply.

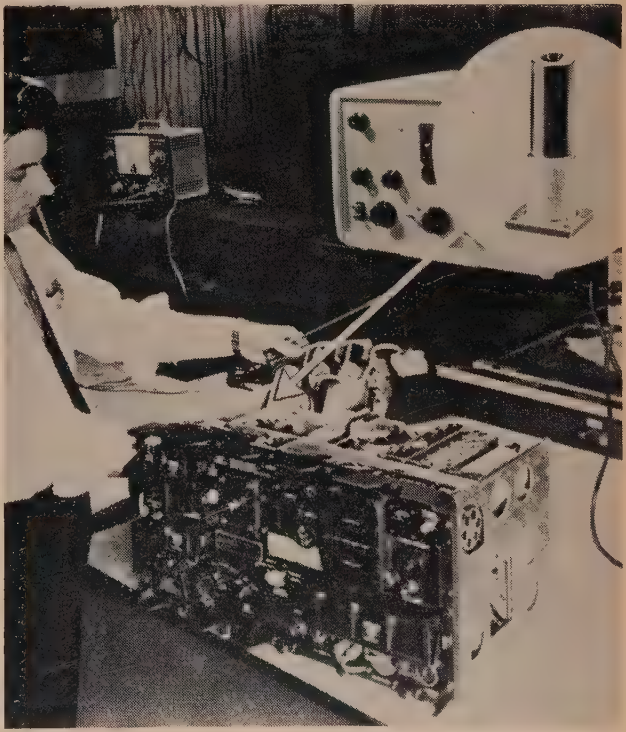
Sintered nylon components may be produced with or without surface oil impregnation for frictional reduction and a micro-porous structure ("Nylasint" 64-HV) holds great promise for electro-mechanical bearing applications. This latter material can retain up to 25% of oil or other fluid by volume with an extremely low bleed rate and is currently being tested by several electronic instrument manufacturers for silent, long life, self-lubricating bearing applications. Typical "Nylasint" components are illustrated in Fig. 7 and it is felt that this technique will prove to be an extremely important development in the course of the next 5 or 10 years in furthering the use of plastic materials for specific industrial applications. For example, ink-filled "Nylasint" 64-HV ink rollers are already in use for ticket printing machinery and conductive bronze-filled sintered nylons may now be produced for specific applications.

Fluorinated Ethylene Propylene. Supplied in raw material form by Du Pont (U.K.) Ltd., under the trade name "Teflon f.e.p." resin, this material is sometimes known as "extrudable" or "melt-processible" "Teflon". This is rather confusing, for, although one of the "Teflon" family of fluorinated polymers, f.e.p. is not to be confused with standard p.t.f.e. Undoubtedly, the new material will capture some existing p.t.f.e. markets, but the ability to extrude f.e.p. at high production rates, particularly in sleeving, will open up wider markets for this excellent electrical insulating material. In addition, injection moulded items may be produced and a wide range of extruded shapes is expected to be available in the future. In general, f.e.p. resin will be a useful addition to the existing range of Fluorocarbon polymers for use where the electrical and chemical resistance properties of p.t.f.e. are required, bearing in mind the narrower working temperature range compared to conventional p.t.f.e.

Future Developments

It is felt that future developments in industrial plastics will proceed in two parallel fields. The discovery of completely new products as a result of planned research will be complemented by developments in processing techniques. Perhaps a typical case in point is the method of coating metallic parts by the fluidized bed system. This system, now gaining widespread acceptance as a method of finishing decorative and household articles,

Fig. 8. "Ferrotron" loading core used in the AN/GRC-19 transmitter/receiver system developed by the Collins Radio Company, Cedar Rapids, Iowa, U.S.A.



AVERAGE PROPERTY VALUE CHART

Property	Units	P.T.F.E.	Fluorosint	Nylon 66	Nylatron GS	Q.200.5	Nylon 610	Mc Nylon 901	Nylasint M4	Nylasint 6G	Nylasint 64-HV
Specific gravity	—	2·1—2·3	2·3—2·4	1·14	1·14	1·05	1·09	1·16	1·18	1·57	0·814
Tensile strength at 23°C	lb/in.^{2}	1500—4000	2000—2500	11,800	12,300	8000—10,000	8500	11,000—14,000	5200	2600	2400
Modulus of elasticity at 23°C	lb/in.^{2}	90,000	190,000	400,000	575,000	240,000	290,000	350,000	215,000	400,000	100,000
Heat distortion temperature @ 66 lb/in.^{2}	°C	132	>250	182	232	103—108	149	218	210	240	170
Coeff. of linear thermal expansion	in./in./°F.	$5·5\times10^{-5}$	$1·1\times10^{-5}$	$5·0\times10^{-5}$	$3·5\times10^{-5}$	5×10^{-5}	$5·4\times10^{-5}$	5×10^{-5}	$4·67\times10^{-5}$	$1·56\times10^{-5}$	$0·321\times10^{-5}$
Flammability	in./min.	Non-inflammable	Non-inflammable	Self-extinguishing	Self-extinguishing	0·8	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
Dielectric strength. Short time	V/mil.	400—500	450—500	385	356	600	470	500—600	450	115	—
Dielectric constant 10^6 cycles	—	2·0—2·1	3·5	3·4	3·5	2·51	3·5	3·1	3·11	11·06	2·67
Power factor 10^6 cycles	—	<0·0005	0·0005	0·04	0·04	0·0002	0·03	0·02	0·06	—	—
Water absorption	% in 24 h	Nil	Nil	1·5	1·5	0·02	0·4	0·8—1·14	0·69	0·22	Microporous material
Chemical resistance	—	Outstanding	Outstanding	Good to alkalis and dilute acids	Good to alkalis and dilute acids	Good to alkalis and dilute acids	Good to alkalis and dilute acids	Good to alkalis and dilute acids	As Nylon	As Nylon	As Nylon

consists of a tank of finely divided plastic which is caused to behave as a fluid by low pressure gas or air applied through the porous tank floor. The item to be coated is heated above the melting point of the powder and dipped into the tank, whereupon a very even coating of plastic powder fuses to the metal surface of the item.

Epoxy coating powders are already available in Britain and the U.S.A. for use with this system and are arousing keen interest as a method of coating rotors, stators, busbars and similar electrical components.

Such materials as the filled p.t.f.e.'s are capable of further development and it is known that a grade of "Fluorosint" of a conductive nature will shortly be obtainable.

An interesting recent development by Polypenco Ltd. is "Ferrotron". This material is a ferromagnetic plastic designed as a non-memory inductive material for high temperature application. "Ferrotron" is capable of being used at temperatures up to 350°C and has a high "Q" factor with a positive temperature coefficient. The material has a very high impact strength, is unaffected by moisture and is available in flexible rod, tape and rigid cores. An application at present in use in the U.S.A. is illustrated in Fig. 8.

Whilst the task of attempting to summarize the future developments of industrial plastics is one of extreme difficulty in view of the tremendous strides made in this branch of the plastics industry alone in the last few years, it is felt that many problems of the industrial designer will be solved by future developments now considered impossible. For example, a large gap now exists between the Polytetrafluoroethylene plastics and the well-known ceramics in terms of available safe working temperatures. A plastic material, readily formed to shapes required and having a working temperature range up to 600 or 700°C would have tremendous potential markets in the electronics and electrical industries. This, and many other developments are foreseen by the writer and it is thus essential for all industrial designers to remain in close touch with future developments in the field of industrial plastics.

8th

U.S. Electronics Reliability Symposium

THE 8th National Symposium on "Reliability and Quality Control in Electronics" will be held at the Statler Hilton Hotel, Washington, D.C., U.S.A. on the 9th, 10th and 11th January, 1962. The Symposium is organized jointly by the American Society for Quality Control, The Institute of Radio Engineers, Inc., the American Institute of Electrical Engineers and the Electronic Industries Association. The general style of the 1962 meeting will be on similar lines to those of the very successful 1961 meeting which was attended by more than 1,250 engineers from nineteen countries.

The area Chairman for the United Kingdom is Mr. R. Brewer of the Hirst Research Centre, The General Electric Co. Ltd., Wembley, Middlesex, who will be pleased to provide further information for those planning to attend the Symposium.

The full list of papers which have been selected is as follows: *Precision through Variations Flow Analysis* Norbet Lloyd Enrick; *A Missile Reliability Reporting System* Irvin R. Whiteman; *Reliability Management by Objectives and Results* Dr. Leslie W. Ball; *Weibell Plans for Failure Rate and Quantile Life* Profs. Kao and Jenry P. Goode; *Full Design Definition is Essential to Reliability* W. L. Hurd, Jr.; *Reliability Research on Components for Space* Erich E. Brueschke; *A Survey of Practical Statistical Tools for Reliability Measurement and Acceptance* Cliff M. Ryerson; *General Usage Assemblies for Navy Electronic Equipment* Thomas E. McDuffie and George C. Neuschaefer; *Contractual Reliability—An Education Program* R. H. Johnson; *The Problem of Human Initiated Failures* Dr. David Meister; *Reliability Program Requirements for Aerospace Systems and Subsystems* Major Vincent J. Bracha, U.S.A.F.; *Optimum Reliability Testing for Space Systems* Catherine Dryden Hock; *Statistical Independence in Reliability Equations* A. M. Breipohl; *Reliability and Forced Air Cooling* J. L. Keller and S. D. Olicker; *Aspects of an Effective Reliability Program Documented by Advanced Bombing-navigation System Reliability Experience* F. W. Blackburn and A. M. Letow; *Estimating Guided Missile System Reliability from R and D Systems Firing Tests* Alvin Steinberg; *Assuring the Quality of Nuclear Weapons* C. E. Smith, Jr.; *Analysis Testing for Improved Circuit Reliability* B. J. Grinnell; *Truncation of Sequential Life Tests* T. L. Burnett; *Determination and Use of Failure Patterns* R. Lesto Horn; *A Reliability Slide Rule* Benjamin Ellison and Victor Selman; *Statistical Methods as Design Tools* Col. Lucian A. Rowell, U.S.A.F.; *Reliability Through Process Capability Studies* George O. Hawley; *Process Acceptance Vs. Lot Acceptance* C. R. Clark and Frank W. Muller; *Some Considerations of Scheduled Maintenance* Richard Meyers; *Component Part Lifetimes Related to a Satellite Environment* D. R. Earles; *Methodology for System Reliability Analysis* Bernard Tiger and Morton Jay Smith; *Increasing Reliability through the QUAD Technique* Ralph M. Fasano; *Management of Equipment Reliability Activities at USASRDL* Thomas J. Edwards and Harry M. Nachmias; *Martin-Denver Auto QC* Robert A. Bennett; *Reliability Emphasis on Production Contracts* James A. Marshik; *Determining Confidence Limits for the Reliability of a System from Tests on Components* W. S. Connor and W. T. Wells; *Acceleration Factor Determination on Glass Capacitors* Lawrence D. Hines; *Operational Reliability of the Athena Computer* G. P. Anderson; *QC Management for Time-Compressed R and D Programs* Frank A. Barta; *Pert-Pep Control for Reliability and Costs* Harry G. Romig; *Maintainability Prediction and Measurement* Mr. Miles and B. L. Retterer; *Development of New Prediction Techniques* I. Bosinoff and J. Klion; *A Comprehensive Education and Training Program for Design Reliability* R. A. Henning; *Failure Analysis* E. W. Kimball; *Screening for Critical Variables Affecting Reliability* Dr. C. H. Li; *Mathematical Analysis of Redundant Matrices* George D. Weinstock; *Practical Aspects of a High Reliability Specification* John Sand and T. W. Gross; *Simulation of Aircraft electronics Maintenance* D. S. Ellis, V. G. Maxon and B. Seid; *Factorial Experiments in Reliability Analysis* C. L. Barron; *Effective Reliability—Through Education* Dr. P. H. Zorger; *Reliability Evaluation by Application Derating* Kenneth W. Davidson; *Equipment Self-Repair Techniques* Jerome Klion; *The Life Distribution and Reliability of Electromechanical Parts of an Inertial Guidance System* L. A. Weaver and M. P. Smith; *CAMESA Reliability Test Program* A. P. Harris; *Reliability Predictions for Multi-mode Electronic Systems* John A. Connor; *The Human Element in the Maintenance Package* Dr. H. W. Page; *Agree in Action* and *Correlation of AGREE Testing with Operational Reliability* Griffith W. Lindsay.

MICROPHONES

By G. R. Pontzen, A.M.Brit.I.R.E.

PART 3.

APPLICATION IN PRACTICE

Model LFV/59 microphones installed in an educational laboratory for schools and industry. Courtesy of the Educational Foundation for Visual Aids.

A survey grouped into three separate parts for the purpose of (1) Classification, (2) Constructional Description and (3) Application in Practice. Particularly in consequence of the substantial and still growing popularity of Tape Recording, the necessity of attaining a basic knowledge of Microphones has acquired a new significance.

EQUIPPED with the more specific information given in Parts 1 and 2, we are in a position to piece the details together and form the pattern required to obtain appropriate solutions to problems arising in the practical application of microphones.

Sensitivity and Impedance Matching

A term which now comes into the foreground of consideration, and which has to be readily understood, is the **sensitivity** of a microphone. Although this has previously been mentioned, it is important for the reader to be familiar with the terminology used and its implications.

"Sensitivity" is an expression which signifies the electrical output obtained from a microphone when its actuating mechanism is subjected to a specified sound pressure. The way in which it is given in technical specifications—and we shall confine ourselves here to the method applied in this country and on a wide, but not exclusive, scale internationally—is in "decibels below 1 volt per dyne per square centimetre"; in the accepted abbreviated form this reads dB (or db) below 1 V/dyn/cm^2. On the face of it this looks complicated but we can take the sting out of it without difficulty if we investigate the expression just a little further.

As stated in Part 1, sound pressure is expressed in dyn/cm^2 and normal speech produces a sound pressure of 1 dyn/cm^2 at a distance of approximately 6 in. from the mouth. If, for instance, the voltage generated by a microphone when energized by speech at that distance were 1 V, then its sensitivity would be given as 1 V/dyn/cm^2. Since the electrical output obtainable from most microphones is, however, of a very much smaller order, the decibel scale is applied to avoid the necessity of juggling with exceedingly minute fractions or decimals.

It is assumed that many readers are familiar with the method of expressing relative values of electric power by means of the decibel. In our case, this method is adopted for describing voltage ratios and in this connection it is particularly important to remember that it can apply *only when the voltages concerned are developed across identical impedances; if this condition is disregarded, the use of the decibel notation becomes meaningless and completely erroneous results will be obtained.*

A small table will be found helpful to a reader not accustomed to the use of decibel calculations and it will, in particular, explain the figures arrived at in the example below. As a standard rule, every 20 dB *added* to a given reference level of zero represents *multiplying* the reference figure by a factor of 10, whereas every 20 dB *subtracted* from the reference figure (in our case 1 V) represents a division by the same number. As we are only interested in values *below* the reference level, our table will be confined to these, as follows:—

0 dB = 1 V =
—20 dB = 0·1 V = 100 Millivolts (mV)
—40 dB = 0·01 V = 10 Millivolts (mV)
—60 dB = 0·001 V = 1 Millivolt (mV)
—80 dB = 0·0001 V = 100 Microvolts (μV)

and so on. At the other end, +20 dB represents, of course, 10 V etc. If we also remember that every 6 dB added to (or subtracted from) any given number of decibels indicates double (or half) the figure represented, we arrive, for instance, at the following:—

−80 dB = 0·0001 V
+ 6 dB = 2 × above figure

therefore −74 dB = 0·0002 V
and:
−80 dB = 0·0001 V
− 6 dB = above figure ÷ 2

therefore −86 dB = 0·00005 V (which is the figure used below

A practical arbitrary example which also gives some clues to the problem of impedance matching may be found useful: The sensitivity of a "low impedance" moving-coil microphone is quoted in its specification as —86 dB with reference to 1 V/dyn/cm^2. This means that speech at 6 in. distance from the microphone would give an output of 0·00005 V assuming that the load impedance is somewhat higher than that of the microphone which, in this instance, is given as 25 Ohms (Ω). If the same type of microphone is to be used in conjunction with a valve amplifier—the input impedance of which is, for example, 1 Megohm (M Ω)—then it will be advantageous to step up the output voltage by means of a transformer. This could conceivably have a turns ratio of 100 : 1 and if it is built into the microphone case, the microphone would be classified as a "high impedance" instrument with a quoted sensitivity of 46 dB below 1 V/dyn/cm^2. As the impedance is proportional to the square of the turns ratio of the transformer, the microphone impedance measured at the secondary terminals of the transformer, would be 250,000 Ω which would still be sufficiently low to match well into the 1 M Ω input of the amplifier with the substantial advantage of an output voltage increased by the turns ratio of the transformer i.e. 0·00005 V × 100 = 0·005 V (transformer losses being of a small order these were not taken into account). The net result is an output from the microphone of 0·005 V for speech at 6 in. distance from the microphone, but it has to be borne in mind that this comparatively high voltage can only be of advantage if used in conjunction with a valve amplifier. It would *not* be applicable with a transistor amplifier where a considerable mis-match and corresponding loss in quality of reproduction would result.

The above discussion can be followed graphically on the **Impedance Matching Chart** which was published in Part 1 of this article and is reprinted here for the convenience of the reader.

At this juncture, it is appropriate to give some more detailed information on certain features, shown in the Chart, which may not be immediately apparent. It will be observed that all low and line impedance connections are carried out with twin screened cable and that lengths up to several miles are permissible, whereas at higher impedances co-axial cable is recommended and the lead lengths are to be kept short. The reasons for these very important considerations are to be found in basic a.c. theory and it would lead us too far off the subject if we pursued them to their source. Some detrimental effects, due to neglecting the recommendations, are, however, worth mentioning as they can provide the reader with valuable pointers towards tracing the sources of trouble in existing installations.

Let us consider the frequent occurrence of hum pick-up being experienced, when the mistake is made of connecting a low-impedance microphone to amplifying equipment by means of a long co-axial cable. We are dealing, in this instance, with magnetic fields inducing voltages in two *unequally* positioned conductors, namely the inner wire and the outer screen. Although these voltages are opposing one another a small residual difference voltage appears at the input terminals and, as it is magnified throughout the whole chain of amplification, can cause a hum level which could completely spoil the required effect. It is preferable to use *twisted* ordinary flex because the conductors are not only equal but also physically positioned in such a way that all induced voltages are equal and opposite, so that no residual voltage appears at the input. The screening provided in twin-screened cable is of secondary importance and mainly provides a convenient method of connecting the microphone case to an earthing point on the amplifier. It is a golden rule to keep both sides of a low- or line-impedance circuit earth-free to avoid so-called earth loops. Only with comparatively short lines can this rule be disregarded without inviting the danger of running into serious hum trouble.

With high-impedance lines other dangers come into the foreground. Here, the screening is of importance to obviate stray pick-up of interference created by, for example, fluorescent lighting or sparks from motors. The necessity for short lines in this instance is mainly created by the capacitance between conductors which, especially with dynamic microphones, causes a serious loss of the higher frequencies—an effect which increases progressively with increase in frequency. For this reason, low-capacitance co-axial cable (*not* simply single core screened) should be used to minimize the effect and the leads kept relatively short, as the capacitance increases in a linear ratio with lead length. Again, it will be observed from the Chart that, where long leads are required, it is essential to use a low-impedance microphone with a transformer coupled into the lead near the equipment, where high-impedance input is provided. In extreme cases it is necessary to either use a line-impedance microphone or a low-to-line impedance transformer near the microphone, with a line-to-high impedance transformer near the equipment.

Yet another point worthy of special mention is the recommendation appearing in the Chart to incorporate a blocking capacitor (in series with the microphone transformer) when connecting to a continental type tape recorder with a d.c. potential in the microphone line, which is provided to energize the condenser microphone often supplied with such machines. This precaution is of advantage, both for protection and to avoid saturation of the transformer core—an effect which causes loss of bass frequencies in the reproduced frequency band.

The reason for showing the two vertical input lines on the extreme right of the Chart, marked "Line input" at 600 Ω level and "Pick-up or Tuner" at high impedance level between 100 kΩ and 1 MΩ, is to provide a warning that these channels, often provided on tape recorders and amplifiers, are unsuitable as microphone inputs in general, as the input sensitivity is insufficient for this purpose.

One more comment on the limited application of the continental 200 Ω moving-coil microphone mentioned in Part 2. Whilst this microphone is often described as "low impedance" in sales literature on continental tape recorders and other equipment, it will be seen on the Chart that there are no lines drawn between the 200 Ω microphones and the 20—50 Ω equipment inputs, the reason being that a considerable impedance mis-match, resulting in deterioration of sound reproduction, would take place. If we visualize lines being drawn as just described, these would be falling from left to right—and this point will be discussed in the following paragraph. Incidentally, it should be mentioned here that, although the same limitations apply, there are British microphones available which specially cater for the continental 200 Ω input and fill a void in music reproduction—no continental ribbon microphone being available.

It will be observed that the general "trend" of the connecting lines between microphones and equipment is to rise from left to right, with a few exceptions which represent either the use of step-down transformers or a compromise of circumstances. Bearing in mind that both scales, left for microphones and right for equipment inputs, denote equal values of impedance, we can draw an important conclusion which will be found exceedingly helpful: *It is always permissible to use a microphone or microphone-and-transformer combination of lower impedance than, or equal to, that of the equipment input.* This applies quite generally and the only limitation to be considered is that the voltage output from the microphone or combination must be sufficient for the input sensitivity provided. In this connection, we want to be aware of the fact that we often deal with substantially higher sound pressures than 1 dyne/cm^2—for example in music reproduction, or alternatively with very much lower values. This, however, involves us in problems where experience is the main factor when decisions are required on choice of type, the number of microphones, and their location relative to the sound source.

Proceeding further into the field of applications we can now consider a natural way of grouping which has a substantial bearing on the choice of microphones: In the first group which we could classify as "Sound Reinforcement" we find rather difficult conditions because we have to deal with at least one loudspeaker in the same locality which tends to feed the amplified sound imparted to it back to the microphone. This results in the vicious circle commonly known as "acoustic feedback" culminating in unwanted howls at one or more frequencies. This group includes the very large field covered by the term "Public Address" (both indoor and outdoor) and ranges over stage equipment in theatres, cinemas, and concert halls, and installations in conference and meeting halls, etc.

In the second group, the feedback problem—although sometimes present in a limited form—does not generally cause serious difficulties. For lack of a better term we might call this group "Sound Reproduction". In this group we can place broadcasting (both sound and television), and recording (disc and tape). A third group which can be called "Telecommunications", includes telephone systems, wireless telephony and intercommunication equipment. A fourth group covers the medical and industrial fields and furthermore there are applications in the military services.

This grouping is quite arbitrary and could be modified or extended at will, but within the scope of this article it appears appropriate, bearing in mind that there is a certain amount of overlapping between groups.

Group 1. Public Address and Sound Reinforcement Systems

In modern Public Address (P.A.) equipment, the microphone plays an eminently important part. An installation incorporating the very best quality amplifiers and loudspeaker systems can be completely spoiled by the use of the incorrect type, or the inadequate quality, of the microphone or microphones used. This incidentally applies to any equipment of which microphones form an integral part.

As we have already briefly mentioned, one of the worst enemies of the P.A. engineer is acoustic feedback. A microphone with a peak in its response curve will limit the volume setting to the level just before feedback commences at the particular band of frequencies in which the peak occurs—the rest of the frequencies will then be attenuated by the "height" of the particular peak above the average level. If, for example, an installation designed for speech reinforcement includes a microphone which has a 10 dB peak around 2,000 c/s and its frequency response is otherwise substantially flat, the volume control has to be set to a level avoiding feedback at this frequency and the general level of reinforced sound will be 10 dB less. The reproduction will be thin and colourless and we may as well do without the equipment altogether. In another case, a microphone may have a peak of a similar order at, say, 400 c/s. The reproduction will sound "boomy" and, due to the comparative attenuation of the higher frequencies, the intelligibility of speech will be extremely poor. Again, we may be worse off with the equipment switched on than listening to the voice of the speaker direct. A level response of the microphone used is, therefore, essential although, under certain conditions, a slightly rising frequency characteristic as found in moving-coil microphones, can be of advantage, particularly for outdoor use. For indoor installations, the ribbon microphone is becoming increasingly popular, as it permits a comparatively high volume setting, due to the complete absence of peaks in well designed models, and to the figure-of-8 polar characteristic which helps to avoid pick-up of sound at right angles to its front-to-back axis. The reader may wish to refer to the curve shown in Fig. 3 of Part 2 of this article which clearly illustrate these observations.

A somewhat controversial point on the selection of microphones for indoor P.A. use is that concerned with the relative merits of velocity (ribbon) and cardioid moving-coil microphones, with particular reference to the feedback problem. The argument in favour of the latter type is the attenuation of sound picked up from the rear compared with the direct sound from the speaker's voice. In the writer's opinion, this advantage is largely offset by the inherently inferior frequency response characteristic of a moving-coil system, compared with that of the ribbon and also the substantially higher sound pick-up from the sides. Experience has shown that a higher sound reinforcement level can, in general, be achieved with the figure-of-8 ribbon microphone.

The slight drawback of emphasized bass frequencies when the speaker is close to a ribbon microphone can be offset by operating a bass-cut control which is incorporated in the majority of up-to-date P.A. amplifiers. A useful point to remember by any microphone user, not only in public address work, is *not* to speak directly into the front of a microphone at close range—this applies particularly to velocity (ribbon) microphones. The air stream from the mouth, especially in the pronounciation of the consonants P and F can cause "blast" effects even where efficient microphone design provides substantial blast screening. It is always advisable, therefore, to speak across the face of the microphone in order to avoid this trouble.

Most modern P.A. amplifiers are supplied with low impedance microphone inputs which allow relatively long connecting leads to be used. Some are fitted with more than one microphone inputs, each channel with its own independent volume control. If more than one microphone is used in the same locality, it is most important that the relative phasing is correct; this means that at any given instant, the polarity of the voltages generated by two or more microphones must be "in step", otherwise strange effects of partial sound cancellation and consequent distorted and unrealistic reproduction occur. This is most important in stage installations where several microphones are in operation.

The feedback problem also takes on serious proportions in churches, where sound reinforcement is being used on an increasing scale. Acoustic conditions in churches are especially difficult and the most efficient way of overcoming these—this applies quite generally to any sound reinforcement installation—is to keep the microphone close to the sound source. The most convenient way of achieving this object is by means of a small light-weight moving-coil microphone suspended round the neck of the user at chest height—a method which is becoming exceedingly popular and requires less skill in microphone technique from the user, the distance from the mouth being relatively constant. No safety precautions in volume level setting are required, as may be the case with a hand or stand microphone when the speaker, by suddenly getting very near the microphone, could raise the level to or above feedback point.

For outdoor P.A. equipment, microphone requirements are somewhat different. As mentioned earlier in the series, ribbon microphones are unsuitable for this application and only pressure operated types will give satisfactory performance. Even with these, precautions against wind noise have to be taken, except with small pencil microphones which give excellent results due to their smooth outline and fine mesh protection. With the larger types of microphones special wind screens are required. From the comments in this paragraph and the knowledge already acquired, the reader will draw the conclusion that moving-coil microphones are the obvious choice for this application.

Reverting to sound reinforcement systems indoors, such as for stage work, concert and conference halls and others, it is usually advisable to use a number of microphones fairly evenly distributed, in order to obtain well-balanced reproduction of the various sources of sound from different directions. Microphones on stages are often suspended from the ceiling or placed in the footlights. In the latter case efficient shock absorbing mountings have to be used to avoid unpleasant interference from footsteps and other vibrations. For any of the above applications, ribbon microphones are, in the writer's opinion, the preferred choice. The necessity to keep the phasing correct was mentioned earlier in the description of this group and cannot be emphasized too strongly if successful sound reinforcement is to be achieved.

Group 2. Sound Reproduction

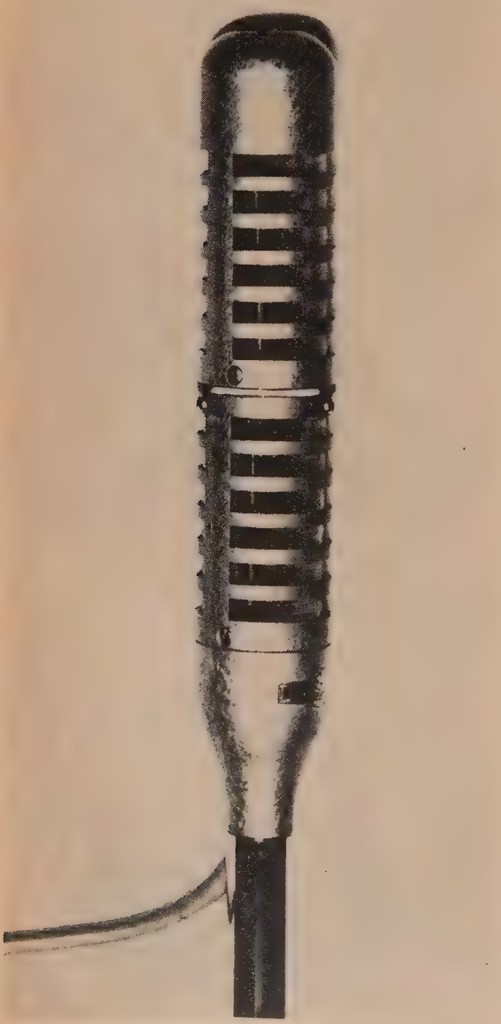
2.1. Sound broadcasting and television

In this field, the very best quality of sound reproduction has been achieved almost irrespective of cost. In v.h.f. sound broadcasting, especially, where the audio frequency range is very extended as compared with any other Service, the choice of microphones is all-important. Whilst, up to quite recently, the ribbon velocity and combined ribbon-moving-coil cardioid microphones were the most popular types, their place has to a great extent been taken by the modern condenser microphones with variable directional characteristics as described before. These cover an almost unlimited field of applications, and also score on size, a vital consideration in television where it is sometimes difficult to keep the microphones out of the picture. For outside broadcasts, the moving-coil microphone is still holding its own, and the same applies to the famous B.B.C. ribbon close-talking and noise-reducing microphone. In live performances, with audiences present, a number of small pencil moving-coil microphones are frequently suspended from the ceiling, to reproduce audience reaction.

2.2. *Sound recording*

In the not too distant past, disc recording was the only method available to produce a permanent record of a sound pattern and the required equipment was far too expensive to be available to any but the fortunate few recording studios and broadcasting Authorities. Microphones were then invariably of the moving-coil or ribbon type. Today, however, with the advent of amateur tape recording over the last few years and its ever increasing popularity, the scope of microphone use has achieved proportions which a few years ago would not have been considered possible. A large variety of microphone types is available to choose from and to suit individual tastes and pockets.

Fig. 1. "Stereolus" stereophonic twin-ribbon velocity microphone. (Lustraphone Model VR65/NS.)



By far the greatest number of a single type produced today is undoubtedly the Rochelle Salt crystal microphone. The manufacturing costs of this particular item are extremely low which is undoubtedly the reason why so many tape-recorder manufacturers supply it with their machines. The arguments for and against this type were given in Part 1 of this article.

Again, the most popular types in use today in this country, disregarding crystal and condenser microphones (domestic type), which are automatically supplied with the tape recorders, are ribbon and moving-coil models. It can be stated without reservation that for reproduction of any musical instrument, especially the piano, there is no suitable alternative to a good quality ribbon microphone. The moving-coil microphone comes into its own mainly due to its versatility, robustness and last, but not least, its economical price range.

In professional tape recording, we encounter a higher standard of all three main types—namely condenser (professional version), ribbon and moving-coil.

Stereophonic recording is one of the newest branches of the tape art and it deserves a few comments at this point, although we cannot enter into the problem too deeply. Many theories have been advanced, and heated arguments have taken place, on the correct placing of microphones and on the type to be used. We shall confine ourselves strictly to amateur recording and two-channel technique and can say first of all that the best way of achieving life-like reproduction is the crossed-twin-microphone method, i.e. two velocity-ribbon-inserts mounted axially above one another at an angle of 90° between the two back-front axes. This combination has given outstanding results over a substantial field of application in music, drama and every-day life. In music, some of the most interesting recordings made were those of solo performances on a grand piano which gave exceptionally life-like results, and orchestra recordings, where the placing of groups of instruments could easily be detected at the centre between the two loudspeakers and progressively to the right and left of the centre—in other words, the well-known "hole-in-the-middle" which is bound to occur with two spaced microphones, is conspicuous by its absence. An illustration of a typical stereo-ribbon microphone is shown in Fig. 1. The top section can be rotated through 100° from the in-line position to give every desired angle. One reason for the preference given to the twin-ribbon over a twin-cardioid microphone is the superior frequency response which, in music reproduction, plays a vital part. There is, of course, the very expensive stereo-condenser-microphone in use at the big studios. However, tests have shown that in some instances members of an orchestra could not tell the difference between stereo-recordings made simultaneously with the twin-ribbon and stereo-condenser-microphones. As a matter of interest: *Price ratio is approximately* 15 : 1!

Tape recording has lately spread its wings more and more into the educational field and the illustration at the head of this article shows an installation where each student has his individual tape recorder and microphone in a separate booth. When a problem is set simultaneously to a group, each student puts his answer on tape and these tapes can subsequently be played back to the group from the central control desk in the foreground. It is apparent that an installation of this nature offers great advantages over ordinary group instruction.

We would become far too involved if we quoted all the known instances in which microphones are used in conjunction with tape recording—just let it be said that the possibilities are practically inexhaustible.

Group 3. Telecommunications

Another substantial field of microphone application which includes perhaps the most ancient use—the ordinary telephone—is that of telecommunications. As we are already aware, the type employed here is, in general, the carbon microphone. A departure from this has recently been made in cases where the speech signal is being amplified to be reproduced through loudspeakers. In this instance, moving-coil microphone inserts replace the carbon ones. The quality of speech reproduction from a carbon microphone through a loudspeaker can be most unpleasant due to granule hiss and inherent non-linear distortion. These faults do not show up too seriously in the ordinary telephone earpiece, its frequency response being limited to a range between 200 and 3,000 c/s.

Intercommunication equipment falls into the same category as the telephone. In many types, moving-coil microphones are also used, for similar reasons to those just stated.

The next item within this group is radio telephony which covers a large variety of systems: Official networks working in conjunction with the ordinary telephone; amateur radio; aircraft radio; police; fire and ambulance services; taxi call equipment. A variety of microphones can be used for these purposes but, again, the moving-coil types are the most suitable.

In aircraft radio, and particularly in aircraft intercommunication, when an engineer outside on the tarmac has to talk to the pilot while the engines are starting up prior to take-off, it would be impossible to maintain contact by means of standard types of microphones. Only a highly efficient noise-cancelling microphone can cope with the deafening noise created by some of the modern jet engines. One such instrument is shown in Fig. 2, mounted on a boom and swivel attachment ready to be fixed to a noise-excluding headset. Small transistor pre-amplifiers, which derive their power from the aircraft power supply, can be fitted either to the headset proper or in the lead; these permit alternative insertion into British and American transmitters, the latter being designed for carbon microphone input.

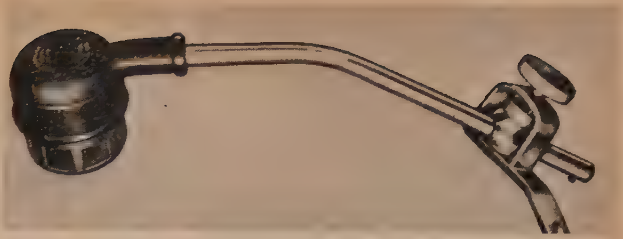


Fig. 2. "Velodyne" noise-cancelling moving-coil microphone. (Lustraphone Model VC52/B.)

In police and taxi radio networks, the fixed control stations are usually equipped with moving-coil, and the mobile stations with carbon or electro-magnetic microphones. Hence, the often quite astonishing superiority in quality of sound reproduction emanating from the control station, compared with that of a mobile transmitter.

Group 4. Medical and Industrial Applications

The main uses of microphones in the medical field are to be found in hearing-aid equipment which can take the form of individual or group aids. In the former, miniature electro-magnetic microphones have the field essentially to themselves, whereas in group-aids, one central high-quality microphone (usually moving coil) supplies a number of individual aids, usually by means of the audio-frequency loop system, or in churches through a plug-in network.

A relatively recent development is the electronic stethoscope which originally used crystal or close-sealing moving-coil microphones as transducers. Severe shortcomings of the former are fragility, high handling noise, poor low-frequency response and general sensitivity, whereas the latter is very inefficient when the seal to the body is not perfect; also, the comparatively large size makes exact location of certain noises impossible, and extraneous sound pick-up is substantial. A new contact transducer which overcomes all the above disadvantages has just been released under the name of "Contadyne" and this transducer will have numerous applications in addition to the medical line. In industry it could conceivably be used for flaw detection in engines and to detect any vibratory deviation from a normal condition.

Surprising applications can be found for microphones in fundamental research, development work and production control, and it is one of the most fascinating parts of a microphone engineer's work to provide answers to problems which can be solved by means of these versatile instruments.

★ ★ ★

It is intended to produce the series of three articles on "Microphones" by Mr. Pontzen in the form of a booklet. Further details concerning this will be given in due course.

Problems Involved in the Manufacture of

SUB-MINIATURE COMPONENTS

By C. St. J. Stevens and I. V. Carey
Fortiphone Ltd.

With the increased use of the transistor in both domestic and industrial equipment the need for smaller and more efficient components is ever present. Manufacturing sub-miniature components presents a three-fold problem: firstly to the design team who have to develop reliable and highly efficient components capable of giving long-term trouble-free performance; secondly to the production team who have to contend with manufacturing and assembling piece-parts of diminutive proportions; and thirdly to the methods team whose responsibility it is to facilitate the assembly work both by devising techniques for the handling and transportation of small piece-parts and by designing suitable jigs and fixtures.

In view of the important role sub-miniature components are now playing in modern equipment, it is of interest to attempt to give some account of the methods and problems involved in the manufacture of but a few of these components.

Microphones

IT IS intended to discuss, firstly, the manufacture of miniature and sub-miniature magnetic microphones and insert earphones which are in general use with such types of equipment as tape recorders, pocket radios, hearing aids and similar apparatus.

These transducers range in size from about $\frac{7}{8}$ in. diam. down to $\frac{3}{8}$ in. diam., (see Fig. 1), and the construction, which is similar for both the earphones and microphones, consists basically of a radiometal polepiece and backplate which is mounted concentrically on an Alcomax ring magnet. This unit, in turn, is soldered into an annular brass ring on the periphery of which is a raised portion to support the diaphragm. The diaphragm, made of 0·005 in. thick radiometal, has a 0·015 in. thick by 0·340 in. diam. armature of the same material spot-welded, concentrically to it. The latter is necessary to provide a magnetic path for the flux from the magnet and also to add mass to the diaphragm to bring its natural period into the middle of the frequency response of the transducer. A coil, wound on a moulded bobbin, is placed over the pole-piece, the ends of which are connected—in the case of an earphone—to the spring contacts which fit into the socket moulded into the plastic back cover, or, in the case of the microphone to the terminal strip which is mounted on the side of a formed metal case. Fig. 2 illustrates these methods of construction in a sectional view.

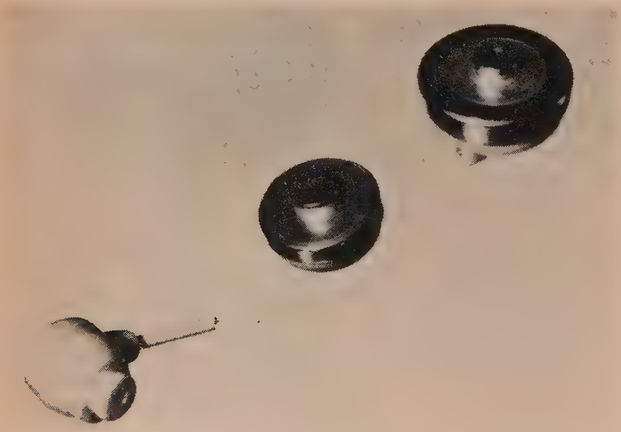


Fig. 1. Examples from the range of sub-miniature microphones and earphones.

It was once the practice to manufacture the pole-piece and backplate in two parts and rivet them together. This particular item can now be produced in one part by the cold heading process which contributes to the efficiency of the unit by reducing the reluctance in the magnetic circuit.

Both the pole-piece and the diaphragm armature are heat treated in an atmosphere of dry hydrogen to obtain maximum magnetic properties.

The gap between the diaphragm and pole-face is critical to the performance of an earphone or microphone and is maintained to within ±0·0005 in. One method which has been employed to achieve the required gap is to solder the magnet and pole-piece assembly into the annular brass ring so that the gap, initially, is some 0·002—0·003 in. smaller than required, and by means of a high speed grinding wheel, material is removed until the necessary gap is achieved. This is a somewhat lengthy procedure as the gap has to be repeatedly measured during the process.

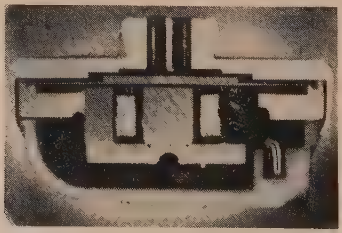


Fig. 2. Sectional view of sub-miniature microphone.

A far more satisfactory method now employed, is that of using a soldering jig to provide the gap between the pole-face and diaphragm support. A step in the jig is ground to within ±0·0001 in. of the required gap. The annular ring, together with the pole-piece and magnet assembly is supported by the jig, automatically providing the gap. A pre-formed ring of solder is placed round the outside of the magnet and the whole assembly heated to solder the two parts together.

Soldering jigs are used for soldering the backplate to the magnet to ensure the pole is concentric with the magnet, after which the magnet and pole-face is lapped flat.

The soldering process, both for the magnet and pole-piece and the complete unit is carried out using an r.f. induction heater. These heaters have been adapted to take specially designed carrying boards. Into each board 100 soldering jigs are inserted in four columns of 25 units. Four work coils, which are placed one above each column, are movable in a vertical direction. By the operation of a lever in one direction the work coils are raised and the board is mechanically moved until a row of units to be soldered is brought into position. By operating the lever in the other direction the work coils are lowered and at the same time the process timer is actuated. This procedure is repeated throughout the length of the carrying board. Other boards are provided so that a continuity of work can be maintained.

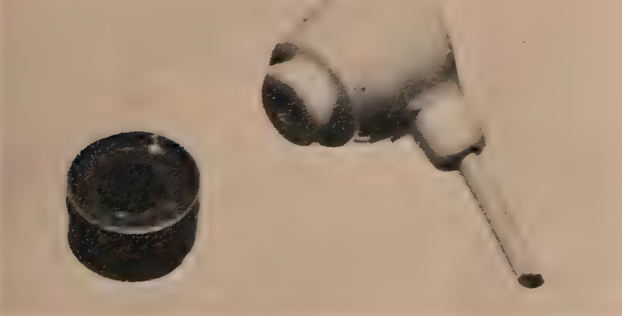
The completed units are subjected to a washing process to remove all traces of residual flux left by soldering.

The final soldered unit has to be inspected for the correct gap, which is checked by means of a dial gauge. At the same time the magnet face is checked for parallelism with the diaphragm seating ledge.

At this stage, further machining operations such as the drilling and the rivetting-on of contacts takes place. Degreasing and final cleaning in an ultrasonic bath completes the work carried out on the unit before final assembly. These units are then stored in dust proof boxes until required.

The diaphragms of the units are blanked out of strip radiometal which has been inspected and selected for flatness. The armatures are also blanked from the same material and planished. Both diaphragms and armatures are then degreased and the armature is heat treated before being spot welded to the diaphragm. The completed diaphragm assemblies are then stored in cylindrical containers. In assembly the containers are placed on a fixture which dispenses to the operator a single diaphragm at a time and a minimum amount of handling is thus involved.

Fig. 3. Earphone of ⅜ in. diam. compared to one of ⅞ in. diam.



Final assembly work is conducted in pressurized clean-air cabinets to ensure that the units remain free from dust and magnetic particles, and for this reason the units are magnetized and stabilized with the diaphragms in position.

It is possibly of some interest to describe, briefly, a sub-miniature earphone of only ⅜ in. diam., the sensitivity and frequency response of which is comparable to that of an earphone of ⅞ in. diam. (Fig. 3).

In this earphone, all piece parts, with the exception of the turned pole-piece and magnet, are blanked and formed out of sheet radiometal. By these means such processes as soldering and lapping are eliminated. The gap between the diaphragm seating and the pole-face is set by a fixture which is used to assemble the seating ring into the outer can. With the availability of the new platinum-cobalt alloy magnet material (Platinax II) it is possible to use a magnet which consists of a single washer 0·340 in. diam. and 0·006 in. thick, clamped between the base of the polepiece and outer can.

The coil is wound direct onto the pole-piece, the surface of which is insulated by a very thin coating of low melting point ceramic. By avoiding the use of a coil former the copper losses in the winding are considerably reduced.

The coil termination consists of a printed-circuit washer held in position at the back of the unit by means of the polepiece retaining nut.

The diaphragm assembly is of the same construction as the larger earphone, the thickness of the radiometal diaphragm and armature being reduced to 0·0015 and 0·005 in. respectively, and the complete unit is housed in a case of thermo-plastic material moulded in two parts, which are cemented together during assembly.

The acoustic performance of each unit, either microphone or earphone, is checked before and after the final capping operation, for full frequency response by means of frequency response tracer, which displays the curve of the response on a cathode-ray tube. A mask is placed in front of the tube face with a cut-out portion which represents the maximum and minimum tolerances of sensitivity allowable (usually ±3dB of the mean frequency characteristic). By supplying sets of masks, the frequency response of any type of transducer can be easily checked.

Inspection:

The following tests are carried out on each unit.

Earphones:

1. Frequency response (a typical frequency response is shown in Fig. 4), and the sensitivity is measured on a 2 cm^3 hard-walled artificial ear, ASA Z24.9.
2. The change in sensitivity is due to the effects of

polarising current
(Polarised earphones are wired so that the polarising current aids the permanent magnet).
3. Impedance, measured at 1,000 c/s.
4. Insulation between winding and frame.
5. Linearity test.
6. Soak test, which consists of supplying a 250 c/s signal to the earphone for a period of 10 min.

Microphones:
1. Free-field frequency response (a typical response is shown in Fig. 5) and sensitivity.
2. Impedance (measured at 1,000 c/s).
3. Insulation between winding and frame.

Volume Controls and Switched Volume Controls

Typical miniature volume controls manufactured are of the order of $\frac{3}{4}$ in. diam. with a volume of 0·135 in^3. In sub-miniature controls the size has been reduced to $\frac{5}{16}$ in. diam. and a volume of 0·016 in^3.

The basis of each control is the resistance track element which, in the cases to be discussed, are of carbon composition type.

Special tracks are produced with low noise and excellent wearing characteristics—typical life tests for the track element being greater than 20,000 operations.

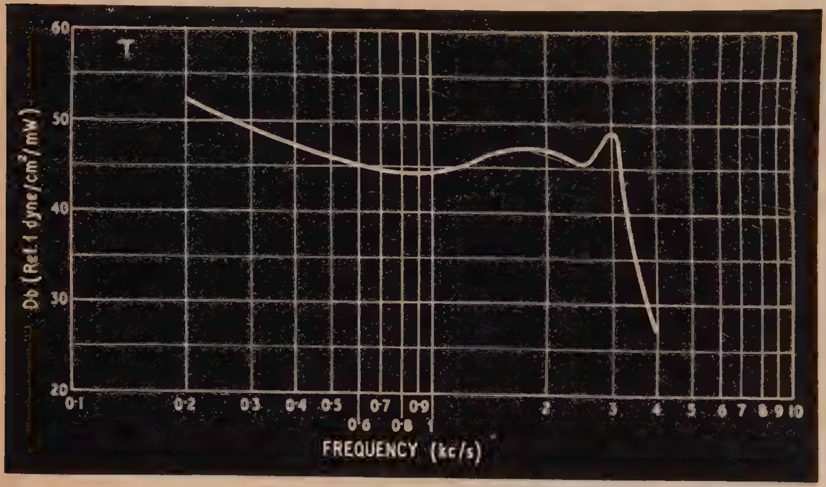


Fig. 4. Nominal frequency response for a 2 cm^3 earphone to A.S.A. Z24.9.

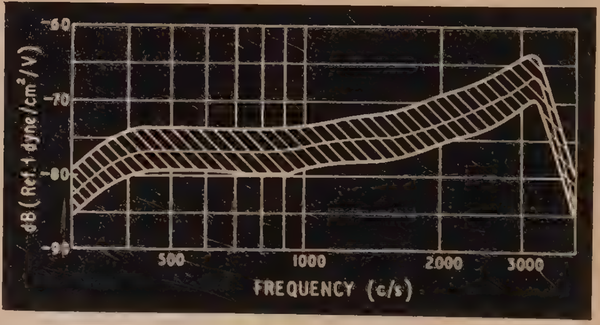


Fig. 5. Typical free-field sub-miniature microphone response.

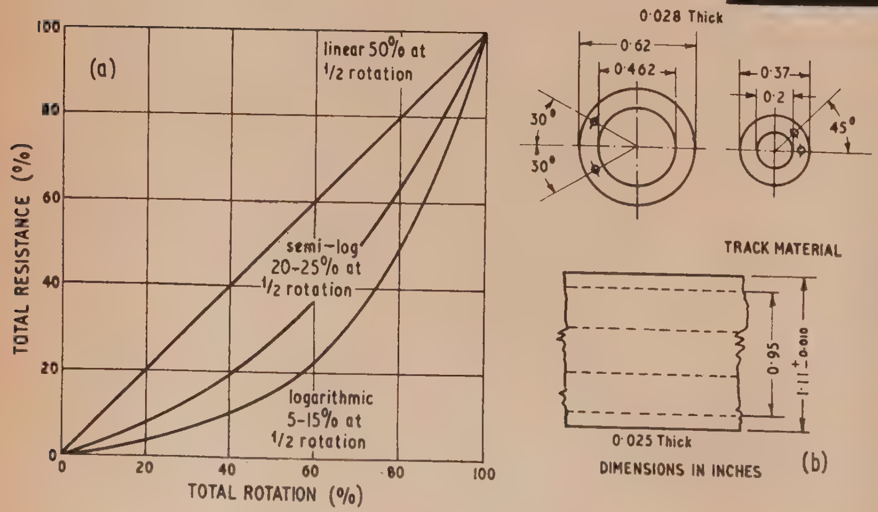


Fig. 6. Typical resistance/rotation characteristics of conducting inks (*a*) and (*b*) dimensions of track elements.

The track elements are prepared from high grade synthetic resin bonded paper (s.r.b.p.) coated with an epoxide-bonded composition. This strip material is coated with either one, two or three sections, each section being of a different resistance gradient so that controls may be manufactured with either linear, log or semi-log resistance/rotation characteristics.

Preparation of the conducting inks is carried out in a dust-free pressurized cabin to prevent the ingress of dust or foreign matter into the inks. When mixing the ink for a multi-section track strip, care is taken to ensure that each resistive ink is compatible to its neighbour, to enable a blend of inks to take place. Typical examples of resistance/rotation characteristics can be seen from Fig. 6(*a*). The required characteristic is determined from the ratio of relative resistivities of adjacent inks, width of ink band and the angle at which the track element is finally blanked from this prepared strip material (Fig. 6 (*b*)).

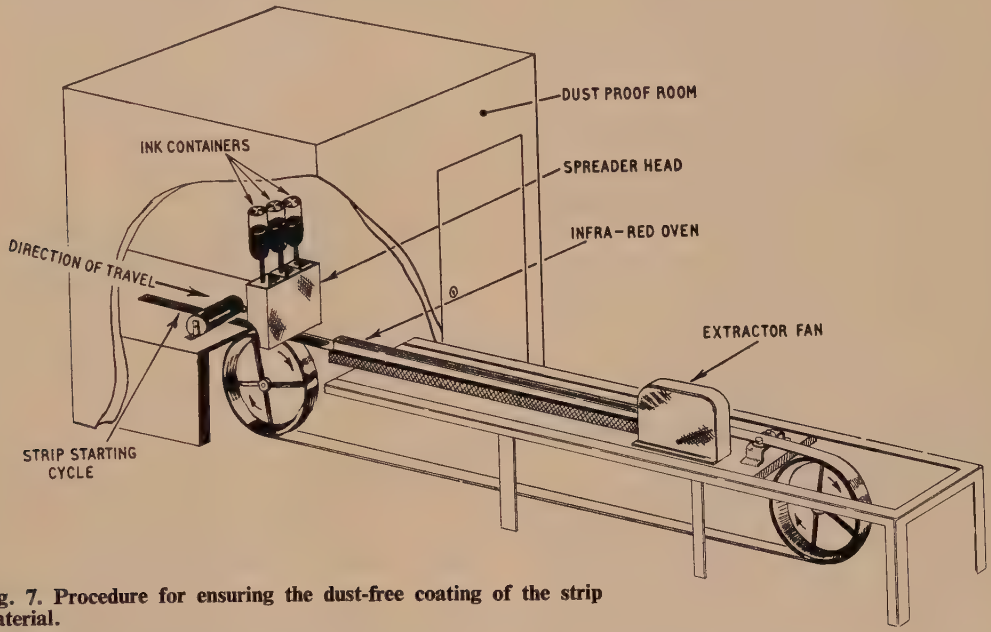


Fig. 7. Procedure for ensuring the dust-free coating of the strip material.

In coating, the s.r.b.p. strip is passed under the spreading head (housed within the dust-free room) directly into an infra-red oven which dries out the solvent and ensures that the strip is in a condition to be handled without fear of damage from the settlement of dust on the conducting surface (Fig. 7).

After spreading and drying, the strip is cured to stabilize the resistive inks. The degree of curing is determined from the resistance/temp./h characteristic for the inks used.

At this stage, it is normal to blank and pierce the track element from the prepared strip material on a compound tool in which the element is returned to strip for further operations. Blanking operations are carried out under clean conditions with all traces of oil and solvents removed from the faces of the tool, the blanking tool being cleaned after each operation by either air blast or brushing, to obviate inclusions of carbon or dust from the base material into the succeeding blanks.

With the track element still in the strip, end coating is carried out on the terminal sections by the application of suitable materials, generally by spraying through a prepared mask. A short period of oven drying follows to remove solvents from the coating.

The purpose of end coating is to provide a low terminal resistance connection between the track element and the riveted terminals.

There are three types of end coating in common use:—

(i) Carbon base I. For terminal resistance in the order of 100Ω.

(ii) Carbon base II. For terminal resistance in the order of 10Ω.

(iii) Colloidal silver base. For terminal resistance in the order of $<10\Omega$.

The choice of end coating is dependent on the overall resistance of the track element with particular reference to the life expectations of the track; in general the life expectancy of the terminal coating is greater with higher resistive values.

Other methods of deposition are available and in use i.e. vacuum depositions of silver and aluminium—but these do not meet the life requirements generally expected.

The next stage involves inspection of the track, and each element is microscopically examined for such defects in the conducting surface as embedded dust and graphite particles from blanking. Electrical tests are made on the finished track elements for total resistance, terminal resistance and sample checks made with respect to the resistance low characteristics.

Assembly of track to base: Assembly of track to base is achieved in miniature controls by riveting the track

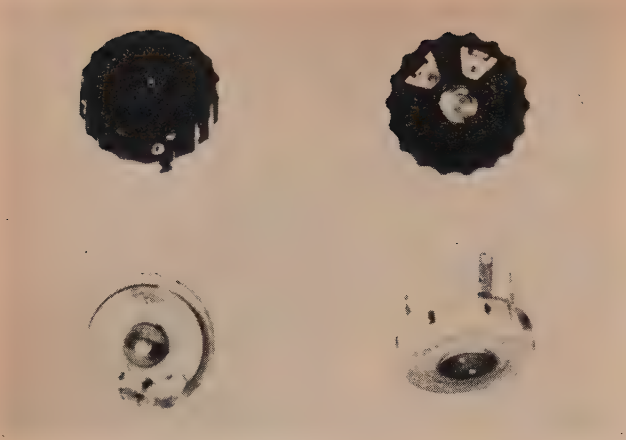


Fig. 8. Miniature controls showing the assembly features.

to the base (which is generally of insulating material), the rivet being turned over onto a suitable terminal lug (Fig. 8). In the case of sub-miniature controls it is desirable to use the terminal rivet as the external terminal lug, to minimize the risk of failure of the terminal which would occur if miniaturized versions of the terminal lug were used. At the same time, the rivet in the sub-miniature control is readily acceptable for printed-circuit applications.

With single-terminal rivet techniques, riveting is normally carried out by either part shearing the diameter of the rivet onto the base or by staking. The latter method has the advantage of providing a keying action of the rivet into the base material which resists any turning action that the terminal might be subjected to in subsequent wiring operations.

Both the preceding methods are being superseded by the use of a completely tubular rivet which is produced by cold-forming suitable lengths of tube 0·030 in. diam. O.D. with 0·015 in. bore. This rivet possesses the great advantage of being easier to turn over, making a superior mechanical and electrical joint.

Wiping contact: The design and production of the wiper plays a considerable part in the life expectations of a volume control. It has been found by emperical methods that the contact point on the track element should be of hemispherical form with a radius of the order of 0·040 in. To maintain good electrical connection between the wiper and the track a contact pressure in the range of 30—60 g is desirable with an optimum of 40 g. The pressure required for any given track is dependent on the relative hardness of the track element, the wipers being produced to match a batch of tracks.

In the production of the wiper, the contact pressure is adjusted by setting the final form tool to the required depth. Control checks are made during the operation to ensure that the required contact pressure is maintained.

Final assembly: Final assembly is carried out under clean condition with pre-cleaned piece parts and assemblies. The knob, which carries the wiper, is assembled to the base by means of the centre spindle. This spindle either takes the form of a rivet or a clamping screw, examples of which can be seen in Fig. 9.

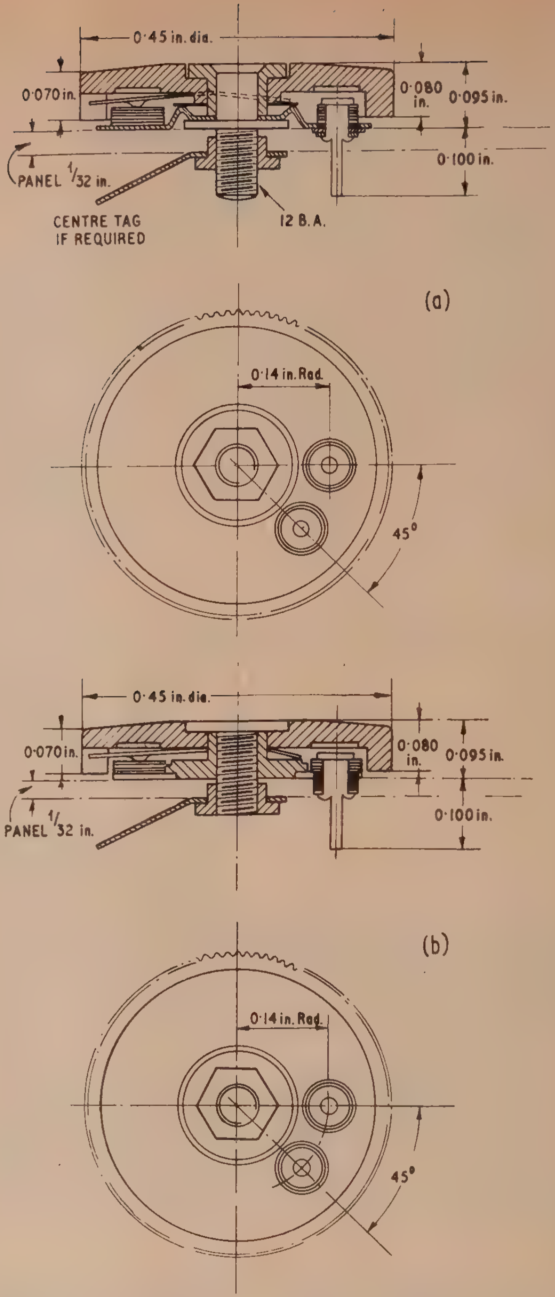


Fig. 9. Two examples of fitting miniature controls to a base.

Switch/Volume Controls

These are similar in all respects to the foregoing, with the addition of a switch incorporated within the body of the control.

With standard materials (i.e. phosphor-bronze, silver-plated; nickel-silver, brass silver plated) it is possible to produce switches with a contact resistance of the order of 0·05 Ω, which is generally acceptable for most low-voltage low current applications.

Under certain conditions i.e. low impedance transistor circuit applications, it is desirable that a contact resistance of the order of 0·005 Ω be achieved. As the contacts of the switch section, in most miniature and sub-miniature controls, are of the pressure-contact type with little or no wiping action, it is necessary to resort to the use of contacts produced from precious metals to achieve the lower contact resistance.

Typical materials in use are silver, silver rhodium plated and various alloys of gold. When it is desirable that the contact shall also possess spring qualities it is often necessary to resort to the use of bimetals in which the base metal is phosphor-bronze, with contacting metals of silver or gold being used.

Testing:

All controls are subjected to full electrical inspection of all the major parameters:

1. Total resistance;
2. Terminal resistance;
3. Hop-on resistance;
4. Hop-off resistance;
5. Resistance law.

The following additional tests are applied to combined switch/volume controls:

1. Switch contact resistance;
2. Switch insulation;
3. Switch/track insulation.

Further checks are made on the mechanical features covering:

1. Switch operation torque;
2. Track operation torque;

and a sample check is made on end-stop torque.

During the entire process of manufacture of these components a strict control is kept on all the piece parts and material used. Without this control the stability of the product would be subject to variations beyond those normally expected for similar conventional size components.

PHOTOMULTIPLIER-TUBE SYMPOSIUM

MORE than 100 delegates from government and university research laboratories and industrial establishments throughout the United Kingdom and abroad attended a Symposium on "Photomultiplier-tube Applications," held at EMI House from 13th—15th September, 1961.

The aim of the Symposium was to provide facilities for an exchange of information on the application of photomultiplier tubes in a wide variety of scientific and industrial fields and to encourage discussion on the ways in which improvements can be made and new fields opened. Judging by the response to lecturers' statements and the lively discussions held after each paper, these aims were apparently achieved.

Mr. Percy Allaway, Managing Director of EMI Electronics Ltd., welcomed delegates to the Symposium and Mr. J. Sharpe, of the EMI Valve Division and in his capacity as Chairman, opened the proceedings by giving a general introduction to photomultiplier tubes.

Mr. K. Rippon of Hilger & Watts Ltd. and Dr. M. A. Ford of Perkin Elmer Ltd. discussed the use of photomultiplier tubes in emission spectrometers and spectrophotometers. The growing importance of the vacuum ultra-violet in the former field was stressed, whilst it became evident that the spectrophotometer requires tubes with as wide spectral range as possible.

An application of spectrophotometer techniques for the measurement of the visual pigments in the living human eye was presented by Dr. W. A. Rushton, F.R.S., of the Physiological Laboratory, Cambridge, and the use of tubes in the far ultra-violet was highlighted by Dr. D. W. O. Heddle of University College, London, who described in some detail his work utilizing satellite-borne observing instruments. The growing importance of photon counting as a means of achieving the highest possible sensitivity from photoelectric and colorimetric applications was discussed by Professor D. E. Blackwell of Oxford, and by Mr. G. T. Winch of the General Electric Company's Hirst Research Centre, who showed how the accuracy of measurements in photometry and colorimetry was being improved by this technique.

Two applications of photomultiplier tubes in colour television were described during the course of the Symposium. Mr. Oxenham of Sylvania Thorn Ltd. dealt with the Zebra colour television display system, while Mr. Hacking of the B.B.C. considered the problems of the colour film scanner. Mr. R. W. Franklin of Crosfields Ltd. described an application of photomultiplier tubes in the Crosfield Scanatron which, while basically a flying-spot scanning system, calls for tubes of somewhat different parameters from those required by Mr. Hacking.

In a discussion related to the nucleonic field, Mr. R. B. Owen of A.E.R.E., Harwell presented a general survey in which he pointed out the importance of photoelectron utilization and the time characteristics of multiplier tubes. Mr. V. A. Stanley of EMI described the Company's work on the development of photomultiplier tubes for tritium counting and Mr. J. R. Brown, also of EMI, discussed the design requirements for large area detectors for alpha particles. An interesting application of photomultiplier tubes in the R. W. Gunson seed sorter was outlined by Mr. E. M. Worster of EMI Electronics Ltd., using information kindly provided by R. W. Gunson.

Lectures were given in the first floor theatre and the ground floor reception room was available as an overflow room where delegates were able to hold discussions in a more relaxed atmosphere. Closed-circuit television linked these two rooms and a sound relay system included a talk-back link so that questions could be put to the speaker from the lower floor.

It is hoped to organise similar conferences in future years on other EMI electronic products, as well as valves and tubes.

COMPONENTS

FOR HIGH-FIDELITY EQUIPMENT

PART 2

By

John Borwick, B.Sc.

High fidelity—often abbreviated to "Hi-Fi"—means the reproduction of sound with as much realism as the present state of the art allows. The detailed specification of high-fidelity equipment has, therefore, to be revised as each new advance is made, but a working set of criteria was outlined in Part 1 together with a discussion of gramophone record reproducing components. The present instalment deals with high fidelity from magnetic tape and radio, and the concluding article covers loudspeakers and amplifiers.

SINCE its development by German scientists in a wartime role, magnetic recording on ferrous-oxide coated plastic tape has spread to every corner of the globe and become the preferred medium in applications as diverse as instrumentation and home recording, video recording and data storage.

In the context of high fidelity, magnetic tape has two distinct functions. First, there are the recorded tapes sold over the counter exactly like gramophone records, with reproducing decks in exact parallel to gramophone record players, and second, the better class tape recorders whose technical performance approaches the criteria outlined in Part 1—usually in conjunction with a high-fidelity amplifier and loudspeaker.

Tape *versus* Disc

It has become fashionable to regard tape and disc as mutually incompatible, forecasting that "tape will make discs obsolete". However, all the signs are that both media will continue to co-exist for a long time yet. Even setting aside the *recording* facility—there has never been a really inexpensive and easy-to-operate disc recorder—tape has a number of technical advantages over disc. The frequency response and dynamic range can easily equal that of the best gramophone records, and the quality of reproduction is virtually unaffected even by hundreds of playings—this is compared to the disc with which each playing (and handling) produces some depreciation. Also, tape is completely free of the two inherent distortions of disc discussed in Part 1, *viz:* "end of side" distortion and "tracking error", since the head/tape geometry and the recording speed remain constant from one end of the tape to the other.

The main point against tape is that it is more difficult to handle than disc—at least to begin with. The free end has to be threaded through the machine and hooked on to the take-up spool, and the fact that the actual recording is invisible makes it more difficult to pick out particular items than on disc.

One answer is to supply tape in a cassette or magazine which is simply dropped on to the deck. Although a number of versions of this idea have appeared in the United States, the only British device to become popular is the Garrard magazine deck. This is fitted on several makes of domestic tape recorder, and the plastic magazines each contain a pair of 4 in. reels. It is then unnecessary to handle the actual tape at any stage. Unfortunately, the running speed of these magazines is 3¾ whereas, as we shall see, the preferred speed for high fidelity is 7½ in./s.

The Tape

Impregnated tapes were once used, but it is now the universal practice to produce recording tapes in the form of a plastic base, coated on one side with a dispersion of the magnetic material plus binder.

The usual magnetic material is γFe_2O_3 powder, needle shaped with an average particle length of 50×10^{-6} in. and a length/breadth ratio of 5 : 1. Binder materials and techniques have improved in recent years so that head wear and ferrous dust depositing are reduced through the incorporation of lubricants and "key" solvents to improve adhesion of the binder to the base.

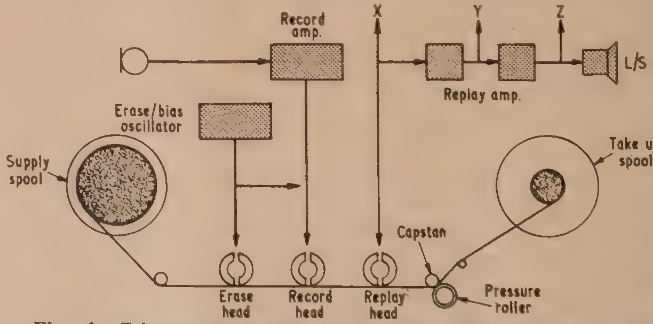


Fig. 1. Schematic diagram of tape recorder, showing typical arrangement of heads and capstan/pressure roller drive. Three outlets for connexion to a high fidelity reproduction system are shown at X (direct head connexion), Y (at output of recorder pre-amplifier) and Z (at external loudspeaker sockets). These are in descending order of quality.

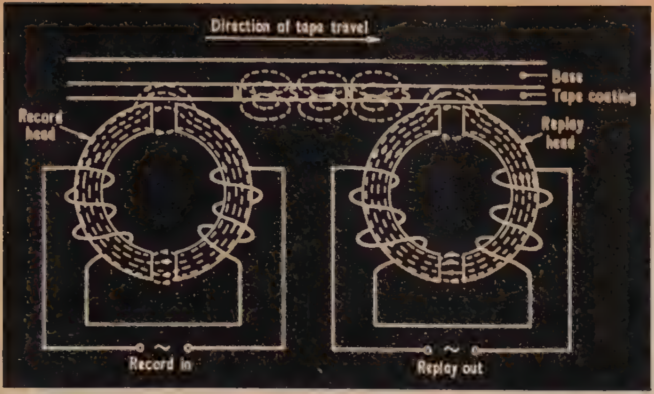


Fig. 2. As the tape passes over the record head, the magnetic particles in the tape coating are left in the orientation dictated by the trailing edge of the head gap. The resultant field links with the high permeability path round the core of the replay head so inducing an e.m.f. in the coil.

There are three thickness grades of the finished tape—Standard (0·002 in.), Long Play (0·0015 in.) and Double Play (0·001 in.). This means that a 7 in. diam. spool, for example, is supplied loaded with 1,200, 1,800 or 2,400 feet of tape depending on the grade. This will produce maximum playing times of 32, 48 or 64 minutes respectively at a tape speed of 7½ in./s.

The least expensive base material in popular use today is cellulose acetate. It is principally used for Standard grade tapes, but is liable to tear and become brittle after a few years. Polyvinyl chloride (p.v.c.) has better mechanical properties than acetate, and has normally been pre-stretched or "tensilized". It costs slightly more than acetate and is popular in the Standard and Long Play grades.

The third, and most expensive base material is polythylene terephthalate—sometimes referred to as "Mylar", though this is in fact a trade name belonging to Du Pont. This together with the "polyester" tapes, is virtually unaffected by humidity or temperature changes and made the Double Play (extra thin) grade possible.

The Heads

A single head is all that is required to reproduce "pre-recorded" tapes, whereas the full complement in a tape recorder is three, covering the functions *Erase*, *Record* and *Replay*, (by means of switching, the latter two functions are normally combined in a single head except on professional equipment).

In essence, all tape heads are electromagnets with a balanced coil wound on a ring-shaped core. The core is generally of Permalloy or mu-metal, laminated to reduce eddy-current losses, the lamination thickness being 0·002—0·005 in. A vertical gap exists at the front of the core, shim-filled and polished, so that as the tape passes over the head its coating completes the magnetic circuit. A gap is usually let into the back of the head to aid hum rejection.

The width of the frontal gap has an important bearing on the performance. In the *Erase* function, a strong a.c. current at a supersonic frequency—typically 45 kc/s, though d.c. is sometimes used on the cheaper battery-operated recorders—is passed through the coil. Here, the requirement is a large spread of the demagnetizing field, so a wide gap is used of 0·003 to 0·2 in. The *Record* head, too, can conveniently have a fairly wide gap, so that the tape is subjected to several cycles of high-frequency signal during its passage through the recording field. Typical values are 0·002 to 0·005 in. though where the *Record* and *Replay* functions are to be combined in a single head, the more stringent requirements of the latter are allowed to dictate the gap width.

During *Replay*, the procession of magnetic fields on the tape must link with the core in such a way that a proportionate current will be induced in the coil. This comes about due to the North/South flux in each recorded half-wavelength preferring the high permeability path through the core to that of the air gap. However, when the recorded wavelength equals the gap width, no flux will exist in the core and the head output will fall to zero. Clearly, if the response of the head is to extend to high-audio frequencies, the gap width should be as small as possible. Until recently, a common value was 0·0005 in. but exceptionally narrow gaps have now appeared, particularly on some heads of Continental manufacture.

Associated with this question of replay-head design is the current tendency to reduce tape speeds, because, of course, each halving of the tape speed also halves the recorded wavelength. To take an example, the recorded wavelength for a frequency of 15,000 c/s and a tape speed of 7½ in./s is 0·0005 in. Therefore, 15,000 c/s is the cut-off frequency at this speed for a head gap of 0·0005 in. Using the same head at 3¾ and 1⅞ in./s would give cut-offs at 7,500 c/s and 3,750 c/s respectively.

It follows that, except for the extra narrow gap heads, 7½ in./s is the recommended speed for high fidelity, and the slower speeds are best reserved for speech recording.

Tape Tracks

Besides differing in gap width, tape heads can have three different gap lengths, according to the number of tracks which the tape is to carry. In the case of full-track recording (used only by professionals) the whole ¼-in. width of the tape is "scanned" by heads having ¼-in. long gaps. Half-track recording (the universal amateur system during the past decade) produces a 0·1 in. wide track just above the centre line of the tape, so that turning the spools over permits a second recording to be made. The last year or two have seen the emergence of quarter-track recording (aimed at a further economy in tape) in which four tracks are accommodated, a mere 0·043 in. wide. Using a 7 in. spool of Double-play tape (for which the playing time per track was given earlier as 62 min. at 7½ in./s), this gives 4 h 8 min. recording at 7½ in./s—or 16½ h at 1⅞ in./s!

While the true high-fidelity system will employ a separate precision tape deck, and derive all amplification and replay equalization from standard high-fidelity amplifiers, a portable tape recorder can be incorporated also, and this is done either by taking a screened lead connexion from the tape head direct, or from the pre-amplifier section of the recorder. The latter arrangement is frequently already wired into tape recorders, the extra outlet being labelled *Hi-Fi Output*, etc. It has the advantage of bypassing the necessarily lightweight power amplifier stages and loudspeaker of the recorder, while utilizing the built-in equalization, etc.

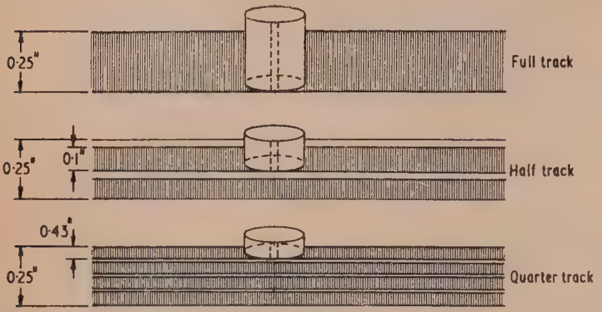


Fig. 3. Using standard quarter-inch wide tape, three widths of track are currently used. Full track occupies the whole tape. Half-track and quarter-track heads "scan" widths of 0·1 in. and 0·43 in. respectively.

The Tape Transport

The primary function of the tape drive mechanism is to transport the tape past the heads at a fixed speed. Short term speed fluctuations—and the consequent variations in musical pitch—are referred to as "wow and flutter", these terms implying variations at 0—20 c/s and 20—200 c/s respectively.

The degree of wow and flutter is specified as a percentage. It is equal to the total r.m.s. frequency modulation present in the frequency bands specified above. Domestic recorders commonly produce some 0·3%, and high-fidelity or professional tape machines 0·15% or less, which is below the level at which it can be detected by ear on ordinary programme material.

The drive is normally applied to the tape by a constant speed motor—synchronous or hysteresis type—through a polished capstan. During *Record* and *Replay*, the tape is gripped between this capstan and a spring-loaded rubber pressure roller. The take-up spools must rotate at the same time, but with a "pull" which can never over-ride that of the capstan. This is achieved on some machines by a second motor, but more usually *via* an auxiliary belt or idler wheel from the drive motor itself. In addition to this take-up tension requirement (and a comparable backward tension or drag on the supply spool) there is the fast wind function whereby either of the spools must be capable of being driven at a high speed, while the capstan and pressure roller grip is relaxed. On recorders employing three motors, high resistance squirrel-cage induction motors are generally used for this operation, the change in torque between this and the simple take-up function being obtained through alteration of the applied voltage.

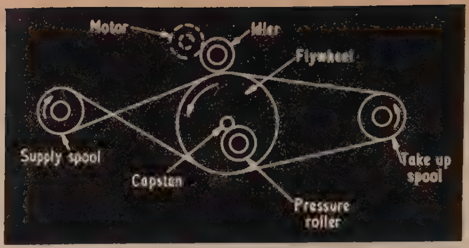


Fig. 4. Showing one method of using a single motor to drive the flywheel through an idler wheel. The drive capstan is mounted on the flywheel shaft, and a cord assembly simultaneously applies appropriately directioned torques to both the take-up and supply spools.

High Fidelity from Radio

The usual way in which radio is introduced to a high-fidelity system is by a tuner unit, which produces an audio signal at about 0·5 V, preferably with a cathode follower output stage to allow as long a lead as is necessary to feed the preamplifier/control unit. Some tuners are self-powered, that is they incorporate a mains transformer and rectifier unit to work from the mains direct. Others take the h.t. and l.t. voltages from auxiliary terminals on the main amplifier chassis. When this has been allowed for, the amplifier specification will include an entry such as: "Power available for tuner, 300 V 60 mA, 6·3 V 1·5 A".

The frequency modulated transmissions on the v.h.f. waveband are preferred for high fidelity. Their frequency response is superior to that of the Medium and Long Wave broadcasts, which are, in any case, drastically filtered on passing through the intermediate frequency circuits of a superhet receiver. This pass band may be no more than ±5 Kc/s in the interests of selectivity, i.e. adjacent channel rejection.

The problem of interference from other stations hardly arises on the v.h.f. band since the radiation—like that of television signals—is rapidly attenuated outside a radius of 50 miles from the transmitter. Electrical noise and interference is mainly a.m. in nature, and so much less of a nuisance on f.m., the circuit suppression being referred to as "quieting". The degree of quieting is related to the r.f. signal input, and so an efficient receiving aerial is essential.

The tuning range of v.h.f./f.m. units is 88—100 Mc/s (88—108 Mc/s for export models). The circuit stages are usually an r.f. amplifier (cascode type), local oscillator/mixer, i.f. amplifier, limiter (Foster-Seeley type) or ratio detector, and a.f. amplifier with low-impedance output or cathode follower. Transistorized versions are beginning to appear, offering better reliability, long life, low power consumption, small size and light weight.

Where reception of Continental or other long distance transmissions is required, it is necessary to include the a.m. wavebands. When this is done in high-fidelity tuner units, special superhet bandpass circuitry is used or, in a few cases, the infinite impedance detector "straight" set has been revived.

To be continued: the final part of this article will be concerned with high-fidelity loudspeakers and amplifiers.

GAS-FILLED AND "SOLID-STATE" THYRATRONS

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THE gas-filled thyratron and the silicon-controlled rectifier are three-terminal devices which permit controlled breakdown in the forward direction. In this direction the "on" condition can be initiated by feeding in a signal of suitable magnitude at the third terminal for a given value of applied voltage, or simply by increasing the applied voltage until breakdown takes place. Once this has occurred the device can only be switched off when the applied voltage is lowered to a value less than the "maintaining" voltage in the case of the gas-filled thyratron and less than the "holding" current in the case of the silicon-controlled rectifier.

When the voltage is applied in the reverse direction corresponding to the "off" condition, both devices are almost in an open-circuit condition provided the maximum value of reverse voltage as given by the manufacturer is not exceeded.

The Gas-filled Thyratron

When it is necessary to control the average power in a circuit it is better to arrange that the controlling element is located in an auxiliary circuit where the power consumption is small. This is illustrated in Fig. 1 where the windings of a relay are connected in the anode circuit of a valve and the current through them controlled by a voltage pulse on the grid. The relay contacts in the main circuit switch the power on and off. If it is necessary to vary the average power in the main circuit, the mark space ratio of the voltage could be altered.

An alternative method which avoids the necessity for mechanical contacts and gives a wide range of control is to use a gas-filled relay or thyratron valve. This type of valve, the construction of which is illustrated in Fig. 2, is voltage controlled and behaves like a unidirectional switch closed by the grid and opened by the anode. Conduction, once started, can only be stopped by reducing the anode voltage below a certain critical potential and not by making the voltage between grid and cathode more negative.

The operation of this valve can be understood by considering the circuit of Fig. 3 with the grid initially connected to cathode and the anode voltage slowly increased. When this voltage reaches a certain value, depending upon the type of gas and the pressure, the anode current starts to increase rapidly and the potential across the valve suddenly drops to a value which may be as low as 8 or 10 V. Thereafter, as the applied voltage increases the current also increases but the voltage drop across the valve remains approximately constant.

If, under these conditions, the grid is made negative to cathode, the anode current is not affected because the negative potential is neutralized by a sheath of positive ions surrounding the grid. The grid, therefore, has lost control of the anode current which will only cease to flow when the anode potential is lowered below a certain critical value. When this occurs, ionization ceases and the grid regains control, the value of negative voltage between grid and cathode deciding the particular value of anode voltage at which breakdown will occur. Fig. 4 illustrates the *Ia*/*Va* characteristics of a thyratron for different grid voltages and Fig. 5 shows a graph relating anode voltage (at the instant of striking) to the control grid voltage. This is dimensionless and known as the control characteristic. It is useful when deriving values of critical grid voltage over a half cycle of anode voltage and, in this connection, is shown in Fig. 6.

The Silicon-controlled Rectifier

The ordinary silicon junction rectifier has two regions each consisting of pure silicon together with an impurity such that mobile positive charges (holes) are freely available in one region and mobile negative charges (electrons) freely available in the other region. When an applied voltage biasses the rectifier in the direction of easy current flow holes are urged into the *n* region and electrons into the *p* region.

If the bias is reversed a small leakage current flows in the opposite direction consisting of holes in the *n* region migrating to the *p* region, and electrons in the *p* region migrating to the *n* region. These are the minority current carriers generated by thermal energy. This current, particularly with silicon, is extremely small until a certain critical voltage is reached when atoms become ionized in the crystal lattice by impact of fast moving minority carriers, and breakdown occurs. The rectifier characteristic is illustrated in Fig. 7.

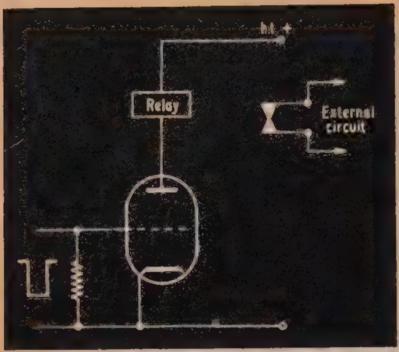


Fig. 1. Simple circuit showing relay controlled by pulse in grid circuit. Mechanical wear of contacts is a disadvantage.

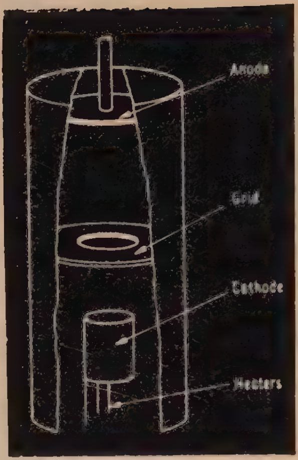


Fig. 2. Construction of the gas-filled thyratron valve.

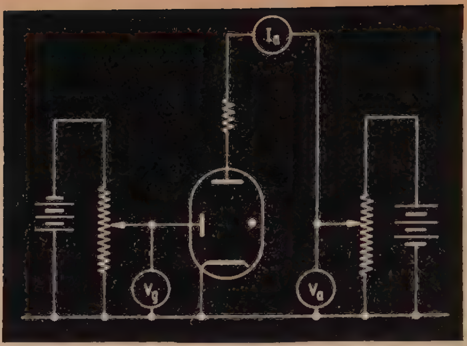


Fig. 3. Circuit for obtaining the control characteristic of a gas-filled thyratron valve.

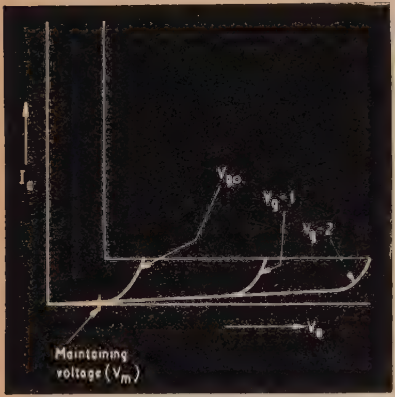


Fig. 4. *Ia*/*Va* characteristics of a thyratron for different bias voltages.

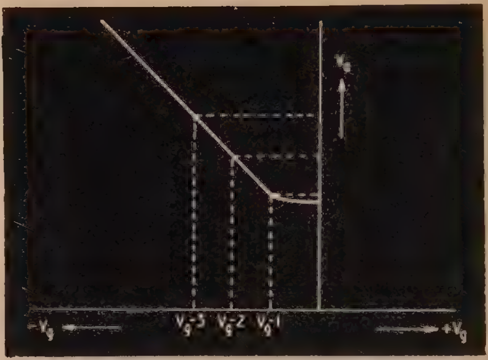


Fig. 5. The control characteristic of a gas-filled thyratron valve.

Fig. 6. Method of obtaining the critical grid voltage curve from the control characteristic.

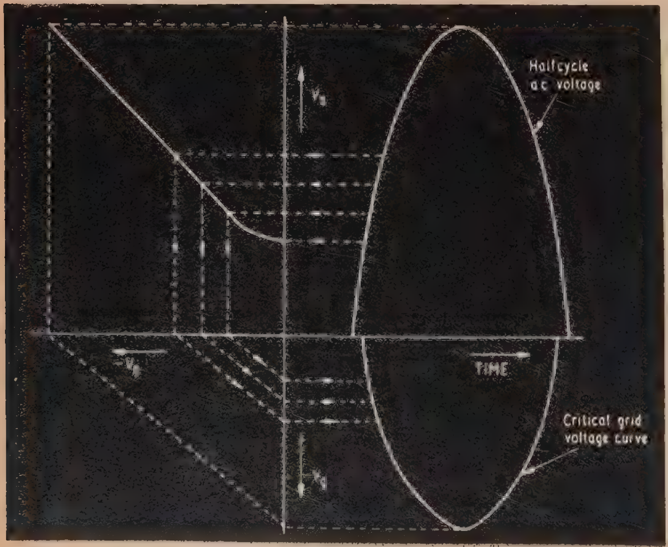
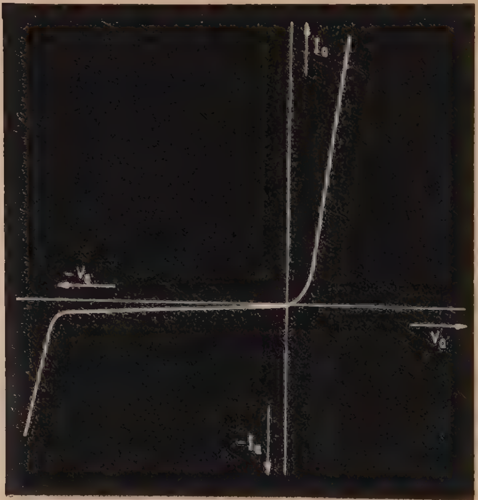


Fig. 7. *Ia*/*Va* characteristic of a silicon rectifier.



The transition from rectifier to transistor (Emitter/Base/Collector) is brought about by the addition of a third impurity region. A *p-n-p* transistor whose third region is *p*-type material, and which is correctly biased has a flow of current supplied mainly by positive holes. For an *n-p-n* transistor the third region is *n*-type material and current is mainly by negatively charged electrons.

In operation, the emitter/base acts as a forward biassed junction diode. Either holes (*p-n-p.*) or electrons (*n-p-n.*) are emitted into the base region. The collector/base is however biassed in the opposite direction and, therefore, the electrical field across the junction is such that almost the whole of the mobile current carriers are swept into the collector region—provided the base is so thin that little recombination of holes and electrons take place. In such a case, the ratio of current arriving at the collector to that leaving the emitter is almost unity but, unfortunately, the thin base is responsible for a low breakdown voltage which is a disadvantage when power transistors are used in some switching applications. If some means could be found to keep the current gain close to unity a wide base would be an advantage where higher voltages were concerned—particularly as it is easier to manufacture and is less variable in its characteristics.

These conflicting requirements have been satisfied in the silicon-controlled rectifier by the introduction of a further impurity layer having the effect of making the device analogous to two transistors whose individual current gains can be added together. Each transistor has a wide base and low current gain.

The silicon-controlled rectifier, therefore, consists of four regions and is illustrated in Fig. 8. When it is biassed as shown, junctions *A* and *C* are in the forward direction and junction *B* is in the reverse direction. p_1-n_1-p_2 and n_2:p_2-n_1, respectively, can be considered as transistors with currents flowing as follows:

1. Leakage current I_{co}, junction *B* reverse biassed.
2. Emitted holes from $p_1(\alpha_1 I)$ junction *A* forward biassed.
3. Emitted electrons from $n_2(\alpha_2 I)$ junction *C* forward biassed.

In the absence of a gate current, the sum of these currents will be equal to *I*, the current flowing in the external circuit. This may be expressed as:

$$\begin{aligned} I &= I_{co} + \alpha_1 I + \alpha_2 I \\ &= I_{co} + I(\alpha_1 + \alpha_2). \end{aligned}$$

$$\text{Therefore } I = I_{co}/1 - (\alpha_1 + \alpha_2).$$

Where I_{co} is the leakage current and $\alpha_1 \alpha_2$ are respectively the current gains of p_1-n_1-p_2 and n_2-p_2-n_1.

The current in the external circuit is, therefore, controlled by the sum of the respective current gains. From this point of view it may be compared to an amplifier with positive feedback whose gain is given by $A/1-AB$, where A is the gain of the amplifier without feedback, and AB is the open loop gain. When AB is less than unity the amplifier is stable. As AB approaches unity the overall gain rises rapidly and finally, when AB exceeds unity, the amplifier bursts into oscillation. Automatic bias or valve curvature ensures that the oscillations are limited to a finite value.

In a similar manner the current through the silicon-controlled rectifier remains at a stable low level corresponding to the off condition until the total current gain approaches and then exceeds unity. When this occurs, the current increases rapidly and is limited solely by the resistance in the external circuit.

The current gain of a transistor is not only a function of base width, but is also dependant upon the voltage between collector and emitter and upon the emitter current. An increase in collector/emitter voltage increases the current gain particularly close to the breakdown voltage because it produces additional current carriers. These are electron hole pairs generated in the depletion layer by collision. A further effect of the increase in voltage is to decrease the effective base width and this also increases current gain as fewer carriers are lost by recombination.

The effect of emitter current increase is to draw carriers of opposite sign into the base region to maintain charge neutrality. This produces an electric field which helps to urge the injected carrier flow from the emitter towards the collector junction. In addition the current increase reduces surface recombination at the emitter. The nett result is to increase the current gain to a value which is sufficient in the silicon controlled rectifier to initiate the "On" condition. Figs. 9 and 10 illustrate current gain as a function of collector/emitter voltage and emitter current.

It is possible, therefore, to use either of the two methods to increase the sum of the current gains in the silicon-controlled rectifier to a value greater than unity. In practice, however, it is usually preferred to maintain the voltage below the breakdown voltage and to switch the device by introducing additional current at the second base, that is to increase α_2. Provided that the current under switch-on conditions is greater than a certain minimum value known as the holding current this condition will be maintained. The current through the "gate" electrode, like the voltage on the thyratron grid, loses control once the main current starts to flow. Therefore, in order to switch off it is necessary to reduce the main current to a value less than the holding current. This is usually automatic on a.c. circuits and must be artificially contrived on d.c. circuits.

Fig. 11 illustrates the chief features of the s.c.r. characteristic and Fig. 12 a typical set of current voltage characteristics. From the latter it can be seen that, with the appropriate value of gate current, the silicon-controlled rectifier can be made to switch on at any value of applied voltage between the approximate limits of 2 V and 300 V.

The Gate Circuit

When the silicon-controlled rectifier is switched on, a

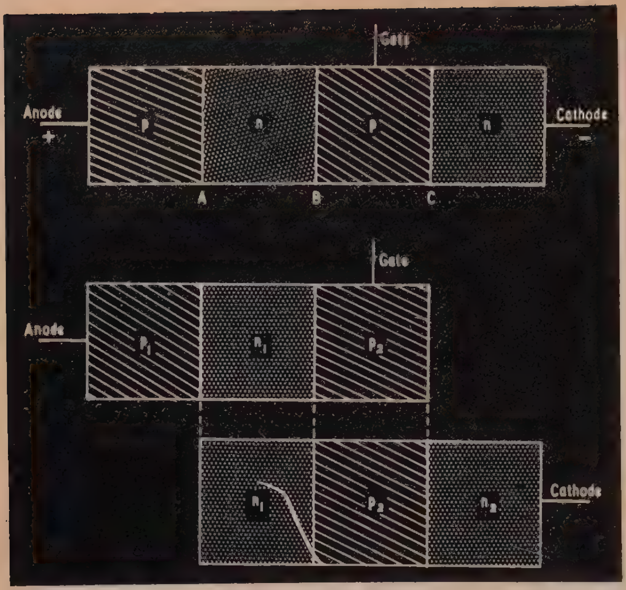


Fig. 8. Block diagram of a *p-n-p-n* structure.

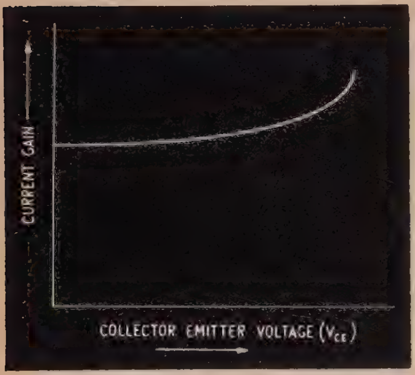
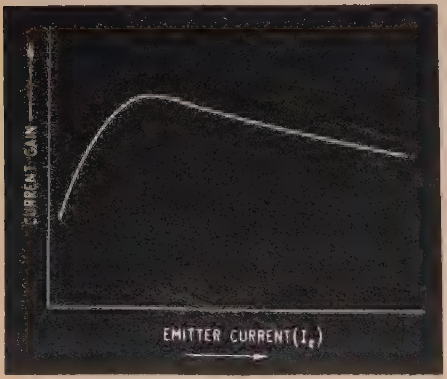


Fig. 9. Current gain as a function of collector emitter voltage.

Fig. 10. Current gain as a function of emitter current.



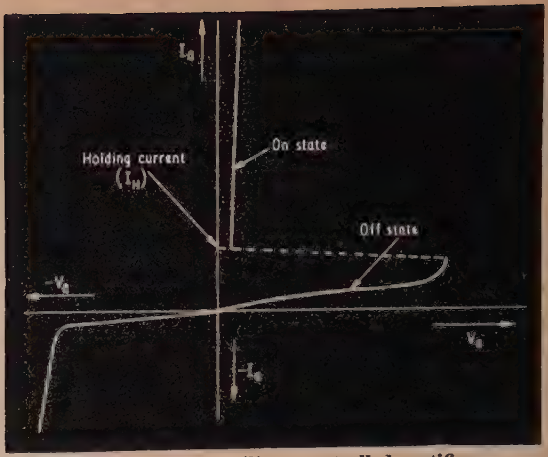


Fig. 11. Features of the silicon-controlled rectifier characteristic.

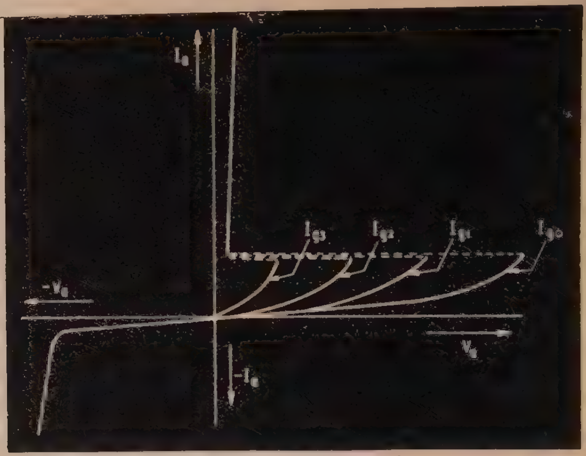


Fig. 12. *Ia*/*Va* characteristics of a silicon controlled rectifier (Limits 2 to 300 V (*Va*) approximately).

voltage is applied between the gate and cathode from a low-impedance voltage source to provide current and power for the gating circuit. It is necessary to be particularly careful about maximum gate current, maximum positive gate cathode voltage, peak allowable gate dissipation and average dissipation.

Given the average gate dissipation, a number of dissipation curves can be plotted, the curves showing the average dissipation when the current flows for the whole of the cycle, for half the cycle and for other percentages.

As an example, assuming an average dissipation of 1 W, the following Table gives the values of current and voltage for 100, 50 and 25% duty cycles. Fig. 13 illustrates these gate characteristics.

VALUES OF CURRENT AND VOLTAGE

100% duty cycle		50% duty cycle		25% duty cycle	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
1	1	1	2	1	4
2	0·5	2	1	2	2
4	0·25	4	0·5	4	1
8	0·125	8	0·25	8	0·5
10	0·1	10	0·2	10	0·25

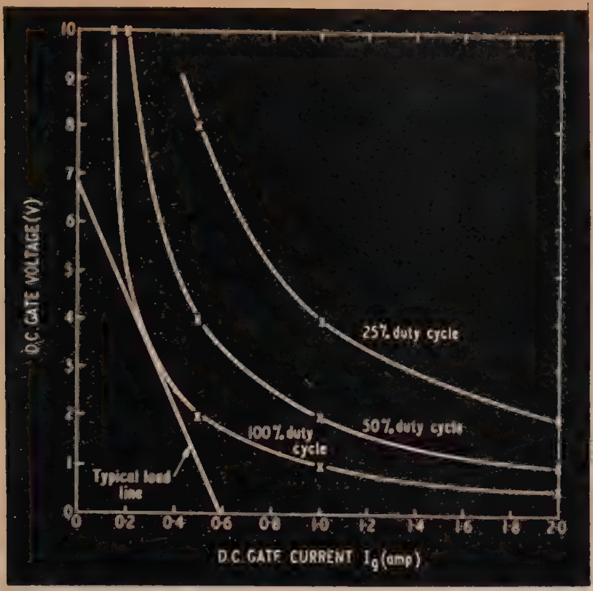


Fig. 13. Gate firing characteristics.

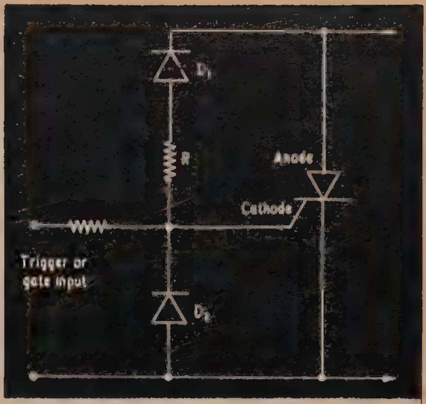


Fig. 14. Clamping Circuit. D_1 and R attenuates positive signals on GATE when anode is going negative. D_2 limits negative excursion of gate.

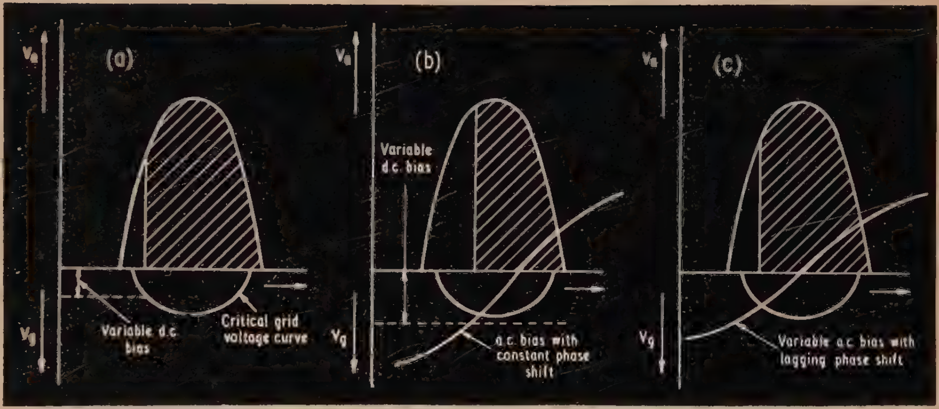

V_a
(a)
V_g
Variable d.c. bias
Critical grid voltage curve
V_a
(b)
V_g
Variable d.c. bias
a.c. bias with constant phase shift
V_a
(c)
V_g
Variable a.c. bias with lagging phase shift

Fig. 15. (*a*) d.c. bias.
(*c*) Horizontal shift control.
(*b*) Vertical shift control.

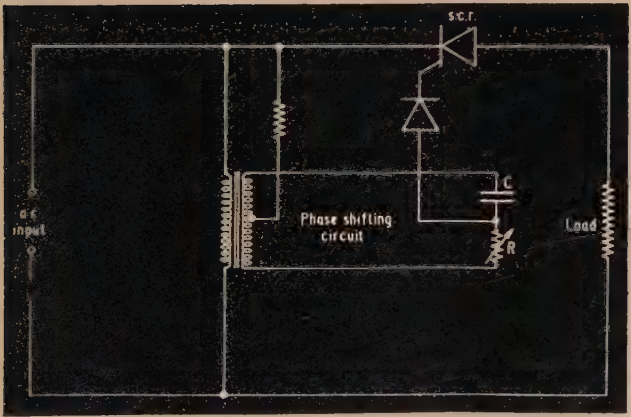


Fig. 16. Half-wave rectifier. Control of current through load.

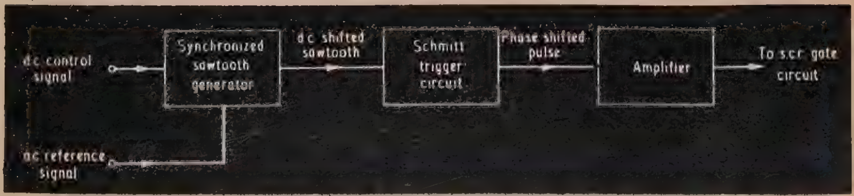


Fig. 17. Block diagram showing production of phase shifted pulse for firing purposes.

When the appropriate gate characteristics have been plotted, the gate circuit load line can be drawn for the particular duty cycle. As there is a minimum gate voltage and current below which the silicon-controlled rectifier will not operate in a satisfactory manner it is as well to calculate the resistance required by the gate circuit from a load line drawn tangential to the particular curve. This ensures positive firing. Typical values of resistance lie between 5 and 20 Ω.

In addition to the requirements outlined above precautions are necessary to guard against excessive leakage current when a reverse voltage is applied across the silicon-controlled rectifier and when, at the same time, a positive voltage is being applied between gate and cathode. The simplest method of preventing this effect is to add a silicon diode in series with the silicon-controlled rectifier or alternatively to provide a clamping circuit (as illustrated in Fig. 14) to attenuate positive signals on the gate whenever the anode goes negative. Another possible source of trouble is excessive negative voltage between the gate and cathode and again this may be prevented by a diode in series with the gate or a zener diode acting as a clamp between gate and cathode.

Methods of Control

1. *The Gas-filled Thyratron.* Many of the uses to which this valve is put involve control of the average value of rectified voltage and hence of current through the load. Several methods are available for this purpose, the simplest being to vary the grid cathode bias between the limits of zero voltage and something less than the maximum critical grid voltage. Control by this means is limited and becomes uncertain when the striking angle approaches a tangent to the critical voltage curve at 90 degrees.

A.C. methods of control are more suitable as these are so arranged that an alternating grid voltage cuts the critical grid voltage curve at a sharp angle of interception giving control over most of the conducting half cycle. In vertical shift control this is done by shifting the phase of the grid cathode voltage with respect to the anode cathode voltage and then varying a d.c. bias in order to vary the angle of interception between the grid cathode voltage and the critical grid voltage curve. In horizontal shift control, the angle of interception—or firing angle as it is sometimes called—is controlled by varying the lagging phase shift of the grid cathode voltage with respect to the anode cathode voltage. Both these methods which give satisfactory control of current are illustrated together with d.c. control in Fig. 15.

For stiffer control the grid may be fired from a pulse source in which the phase of the pulse is variable with respect to the anode cathode voltage. Provided a steep leading edge is used, only a small pulse amplitude is needed.

2. *The Silicon-controlled Rectifier.* Similar control methods to those used with the gas-filled thyratron valve are also available for the silicon-controlled rectifier provided the precautions mentioned previously in the gate circuit are taken. However, d.c. control and a.c. phase control methods are unlikely to be used to quite the same extent as the gas thyratron where it is comparatively easy to increase the a.c. grid cathode voltage in order to sharpen the firing angle. With the silicon-controlled rectifier, this is not always possible because of the restriction of average dissipation in the gate circuit. In addition, firing characteristics are both temperature dependant and have a fairly wide spread. Fig. 16 illustrates a suitable phase shifting circuit for use with the s.c.r.

It would seem apparent that a more satisfactory method is to fire the controlled rectifier with a long-duration steep-fronted pulse having a variable-phase leading edge and a fixed-phase trailing edge. The block diagram of Fig. 17 illustrates how this may be carried out.

When higher voltage applications are needed, silicon-controlled rectifiers may be connected in series provided that the individual gates are fired from sources which are isolated from each other. Pulse transformers with multiple secondaries are suitable for this purpose. In addition shunt resistors should be provided to equalize the voltages across the series elements, together with capacitors for protection from high-voltage transients which are more severe with the silicon-controlled rectifier due to the very fast switching times.

Parallel operation is also possible for higher current applications provided that the forward characteristics are matched for equal current sharing and each unit fires at low anode voltages.

Conclusion

Both the gas-filled thyratron and the silicon-controlled rectifier may be used for applications such as the control of motor speed, the replacement of mechanical relays, inversion of d.c. to a.c. and many other uses. Certain advantages, however, which lie with the controlled rectifier make it likely that it will be used in the future to a greater extent than the gas-filled thyratron despite the fact that at present it cannot handle, as a single unit, peak voltages much in excess of 300 V. The advantages that make the controlled rectifier an attractive proposition are a low forward voltage drop giving high efficiency, faster turn on and shorter recovery time, absence of heaters, and a rigid mechanical construction ensuring reliability in conditions of severe mechanical shock.

Already the silicon-controlled rectifier is established in a variety of conventional circuits and is giving satisfactory operation. Because of its high power, high speed capabilities (an average switching time may be half a microsecond) it is a valuable new tool in the hands of the circuit designer and a welcome addition to the already wide range of semiconductor devices.

E.R.A. REPORTS

The Reports summarized below are available from the Electrical Research Association, Leatherhead, Surrey

Performance of Insulated Carbon-resin Film Resistors

REPORT REF. Z/T105 is a continuation of a previous E.R.A. Report Ref. Z/T95, dealing with a particular type of Grade II fixed resistor. This consists of a glass tube, the outside of which is coated with a carbon-loaded resin film. The terminal wires project into the tube and are fixed to it by a conducting cement which also serves to connect them electrically with the resistive film. The film is protected and insulated by a mica-filled resin layer moulded around it, and this moulding also helps to retain the terminal wires in position. The glass tube may or may not be rotated about its axis as it is being coated with the carbon-resin mixture and examples of both methods of manufacture have been tested.

The conclusions reached in Report Ref. Z/T105 are summarized as follows:

Over a period of at least 4,000 h the effect on resistors, with unrotated base tubes, of the a.c. life test carried out at the E.R.A. is not seriously different from that of the life test normally imposed upon Grade II fixed resistors.

A.C. life tests which have continued for over 15,000 h show that resistors made without rotating the base tube behave well during the course of this type of test, although the large spread in the results of intermittent loading, when extended over this period of time, suggests that this may be more harmful than continuous loading.

It appears that rotating the base tube during manufacture produces resistors with undesirable characteristics. The behaviour on a.c. life tests of resistors made with rotated base tubes cannot be predicted with any certainty except to say that the initial resistance changes on tests of this type are, in general, numerically greater than those of resistors made without rotating the base tube. It should be stated, however, that the resistors made by forming the film in a rotated base tube were specially made experimental samples and are not commercially available.

Duplicate a.c. life tests with resistors from a different batch have confirmed these results over a period of 7,000 h.

Further tests have confirmed the finding that the behaviour of complete resistors is the same whether they are raised in temperature by a.c. loading or by storage at approximately the same temperature in an oven. They have not confirmed that the resistor elements with rotated base tubes behave differently depending upon the method of raising the temperature.

A d.c. life test has confirmed the manufacturer's results for resistors made without rotating the base tube and it appears that, for this type, d.c. loading at 0·9 W in air at room temperature is no more harmful than an equivalent a.c. loading. Resistors made with rotated base tubes seem to be more seriously affected by a d.c. load than by the equivalent a.c. load.

The results of the d.c. test also suggest that there may be some undesirable effect from light d.c. loading under damp conditions and tests of this nature are in hand.

The full report: *The Performance of Insulated Carbon-resin Film Resistors II*, by F. G. Rivers, is obtainable price 10s. 6d., plus 6d. postage.

High-stability Carbon-film Fixed Resistors

THE SUBJECT of d.c. failure in moist atmospheres of high-stability carbon-film fixed resistors is discussed in Report Ref. Z/T124.

The report explains that rapid failure of Grade 1, high-stability carbon-film fixed resistors during tropical exposure with light d.c. loading (0·2% of the rated wattage) has been reported from a number of Government Establishments. In some tests on values of 10,000 Ω and above, all failed within 7 days, with both insulated and uninsulated types. In other tests, failure was confined to the higher values (1 MΩ and above) and occurred after periods of 14, 28 or 84 days. Failure took the form of open circuit or large increase of value. In some reported tests, particularly with insulated types, behaviour was satisfactory.

Under light a.c. loading very few failures had occurred after 84 days' tropical exposure and no failures occurred with unloaded resistors.

The E.R.A. was requested to investigate the cause of failure under these conditions and to study the reasons for the marked differences in behaviour in different testing laboratories.

Six 100 kΩ (1·5 W) resistors of Make A having a transparent varnish coating through which the carbon track was visible, and six 150 kΩ (1·5 W) resistors of Make B coated with an opaque paint, were subjected to tropical cycling treatment with light d.c. load (0·2% of the rated wattage) for over 500 days without a single failure or any significant change in value occurring, or any sign of deterioration being apparent on superficial examination. The exposure had taken place inside a Pyrex glass desiccator containing water, the resistors being mounted several inches above the water level. During the exposure the desiccator was placed within a temperature controlled chamber.

Since rapid failure had been reported at the Royal Radar Establishment under nominally the same conditions, it was arranged to send some of these resistors which had survived the E.R.A. tests to R.R.E. for further test. All six of Make A and four of the Make B resistors were accordingly set up in the R.R.E. test chamber. One of Make A failed in 7 to 17 days and three of the same make in 24 to 38 days. At this stage (38 days) all six of Make A were returned to the E.R.A. for examination, but the exposure of Make B, none of which had failed, was continued. Two of Make B eventually failed after 66 days and the other two after 84 days. These were also returned to the E.R.A. The resistors had been tested at R.R.E. in a Perspex chamber containing a trough of water heated to 35°C by an immersion heater. It was reported that no condensation was apparent on the resistors.

On examining the resistors of Make A, all showed, through the clear varnish, bare patches of ceramic from which the carbon had been removed. At the places where failure occurred the whole width of the track was bare—often over two or three consecutive turns. The bare patches were not everywhere the colour of the ceramic, but frequently pale brown. The varnish was not affected except locally in the region of the final open-circuit, where some blistering was evident.

The report concludes that failure of carbon-film fixed resistors under light d.c. load is primarily caused by moisture penetration of the protective paint or varnish coating, and the consequent electro chemical oxidation of the carbon. The heat dissipated under such loading is not sufficient to drive off the moisture. Failure occurs by eventual open-circuiting of the carbon track, and is especially rapid where actual condensation of moisture occurs on the resistors under test; differences in the amount of condensation may explain inconsistencies between results obtained in different testing chambers.

Similar forms of electrochemical attack could also occur with other types of thin film resistors. Attention should, therefore, be paid both to the effect of moisture on the protective coatings of such resistors and to the susceptibility of the resistive film to electrochemical attack under moisture conditions. The results emphasize the need for close control of the humidity and condensation conditions when testing components which are subject to electrochemical deterioration.

The full report: *High Stability Carbon-Film Fixed Resistors. D.C. Failure in Moist Atmospheres*, by I. D. L. Ball and R. G. J. Butler, is obtainable price 7s. 6d., plus 6d postage.

Calculation of Axial Short-circuit Forces in Transformer Windings

REPORT, REF. Q/T151, explains that an individual turn of a transformer winding through which current is passing may experience two kinds of force—that which is due directly to the magnetic field in which the turn lies and to which the current itself gives rise, and that which is due to the direct physical thrusts of its neighbours.

When tappings are made in one or both of the concentric windings of a transformer the magnetic field may be such that the axial magnetic force exerted on the successive turns of a particular winding changes sign several times along its length. In such cases complications arise in the calculation of the total axial compressive force at a given point of the winding for it is found that because a turn of a helical winding can push its neighbour physically but cannot pull it, the exact location of that section of the winding responsible for the physical thrust is not immediately obvious.

Analysis of the conditions under which adjacent forces may be summed algebraically shows that there are points of the winding across which summations cannot be made without careful investigation of the validity of the process and amongst these points is at least one across which summations cannot be made at all. Expressions representing the thrusts of long sections of a winding are, therefore, built up of a number of smaller basic thrusts each of which involves no awkward point and is therefore obtained by straightforward integration. These basic thrusts are then added together, the conditions under which this can be done being incorporated into the formula with the aid of a simple notation. A methodical way of summing thrusts having been established, the points across which summations cannot be made are determined and all the required formulae are greatly simplified.

For a given transformer, and also a given arrangement of tappings, analytical expressions are derived for the compressive forces in terms of the magnetic vector potentials in the two windings, formulae for which have already been deduced by Rabins. The method of solution is outlined for the general case and numerical values are computed in two simple cases.

The full title of the report is: *A Method based on Maxwell's Equations for Calculating the Axial Short-Circuit Forces in the Concentric Windings of an Idealised Transformer* by P. R. Vein, and copies may be obtained price 15s., plus postage 6d.

SUBMISSION OF ARTICLES

Technical articles will be gladly considered for publication, payment being made by arrangement. Articles should preferably be from 3,000 to 4,000 words, but no rigid limit is imposed. Manuscripts should be typewritten, in double spacing, on one side of the paper only. Diagrams may be drawn in pencil provided that they are clear and adequately lettered. For half-tone illustrations, glossy prints are preferable. While every care is taken of MSS. submitted, no responsibility can be accepted in case of loss.

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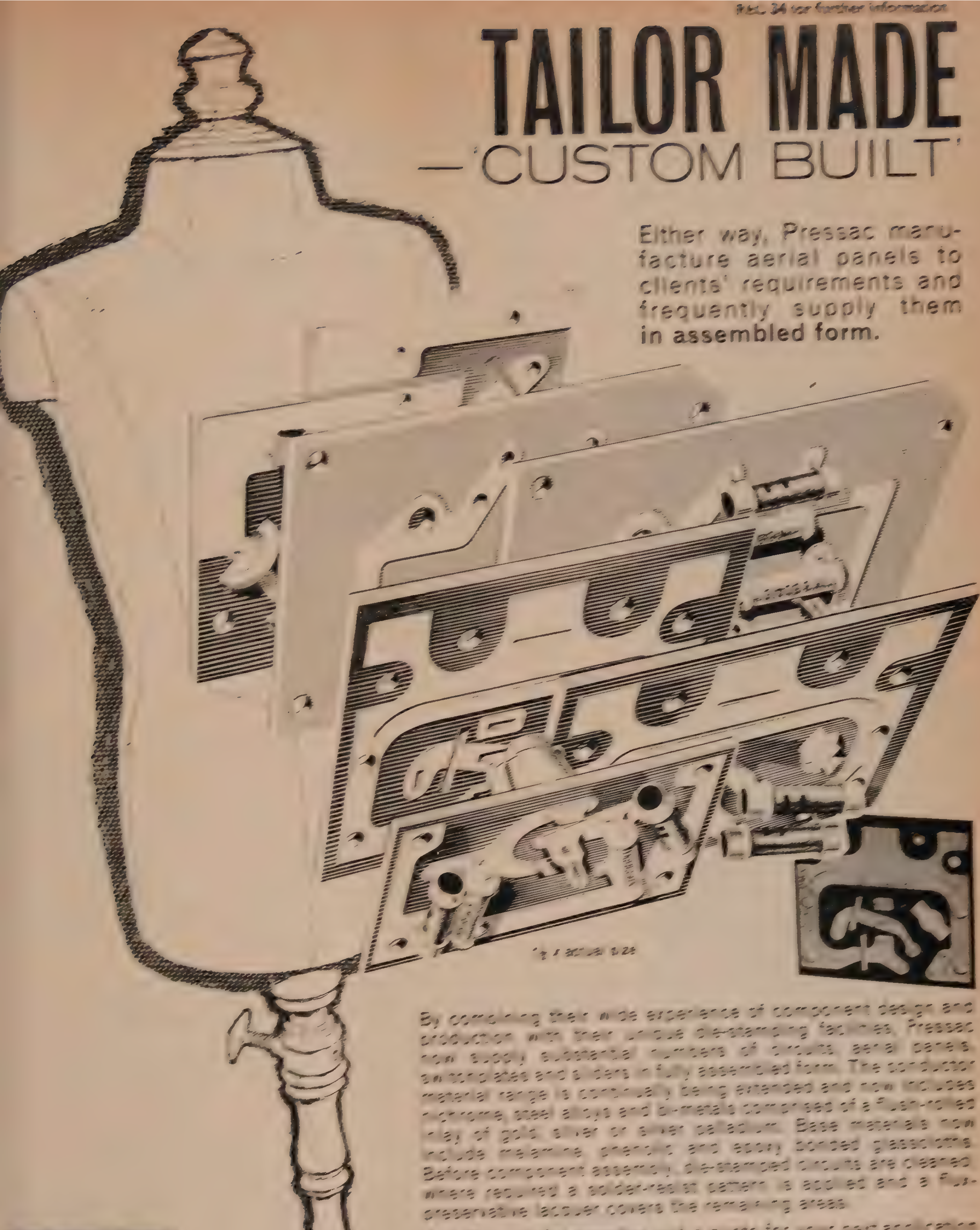

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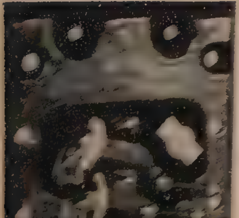

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REC **35** for further information

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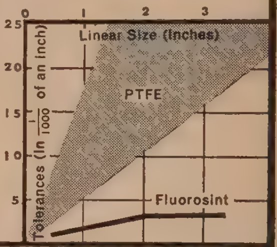

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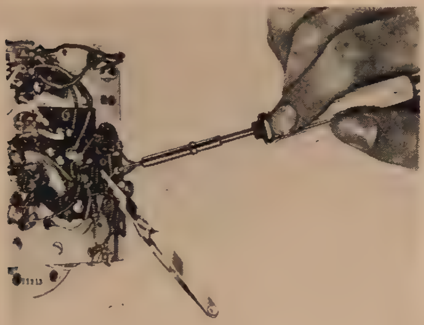
PP/A16/61

NEW COMPONENTS

Heat Sink

Antex has recently placed on the market a heat sink for use when soldering transistors



Antex heat sink in use.

with the Antex precision soldering iron. The illustration shows the device in use.

REC 101 *for further details.*

Antimony-clad "Nilo-K"

Johnson Matthey & Co. Ltd. announce that they can now offer to manufacturers of semiconductor devices sample quantities of "Nilo K" strip clad on each side with 0·5% gold-antimony. It is hoped that production quantities will be available early next year.

The strip is available in widths between $\frac{3}{32}$ in. (2·4 mm) and 2 in. (50·8 mm), in thicknesses down to 0·005 in. (0·13 mm). The thickness of cladding that can be supplied on each face is either 11·5% or 18·75% of the total thickness.

REC 102 *for further details.*

Four-layer Germanium On-off Switch

Tung-Sol Electric Inc. have now available, through Walmore Electronics Ltd., a new semiconductor device termed the Dynaquad. This is a germanium, alloy junction, *p-n-p-n* unit which can be turned on and off by applying small signals to the base. It is turned on by applying a negative pulse and turned off by a positive pulse. The device is useful in small signal switching, driving and pulse forming applications. It's inherent binary characteristic should make it of use in computer, control circuits and in digital techniques generally.

REC 103 *for further details.*

Automatic Spraying and Stoving Machine

Automatic Equipment Ltd. has developed a fully automatic spraying and stoving machine that is believed to be the most advanced in the field of paint shop automation in Britain.

It is designed for the fast and economical paint finishing of a great number of items and will have many obvious applications in the electronics industry. The unit is designed to provide a high work output from limited floor space. It is totally enclosed to prevent dust settling on newly-painted work and is easily operated by unskilled labour—an important factor for the reduction of labour costs.

Controlled paint application is ensured, with minimum paint overspray waste and consistent process time for flash-off of solvents, stoving and cooling. This reduces to a minimum the percentage scrap due to variable human element control, and mishandling of wet painted work which can result in substantial savings in running costs. A metal pre-treatment station to enable complete process without handling is available as an optional extra.

A mechanical traverse with a full range of stroke adjustments is supplied. One or more traverses can be fitted to a unit with a complete series of motions, including vertical, horizontal, arc spraying and internal coating.

Any form of stoving can be incorporated, including infra-red, forced draught or a combination of both, using gas, electricity, oil or steam as the heating medium. In addition, the paint extract system has a filtered air inlet and combines the best in water curtain rear sheet with efficient scrubbing by water jets.

The unit is completely flexible and can be designed to spray and stove at a predetermined output rate, with the work set at 3 in. pitches or multiples of 3 in. pitches. A special feature of the design allows the fitting of a selective spray device to prevent spraying on unloaded work carriers.

All units are custom built and moulded to suit individual shop layouts, outputs and process times. And if required, can be supplied in flameproof form for handling materials of all classes.

REC 104 *for further details.*

Polystyrene Capacitors

An entirely new range of miniature polystyrene capacitors designed for transistorized and low-voltage circuit applications is now available from the Telephone Manufacturing Co. Ltd.

Capacitor SM.125695 (full size).

Despite their extremely small size, all these capacitors are for normal working voltages of up to 50 V d.c. Capacitance values are from 0·0005 μF to 0·5 μF with a closest standard tolerance of ±1·0%. Sizes of individual capacitors range from $\frac{9}{16}$ in. (length) by $\frac{3}{16}$ in. (diam.) to $1\frac{15}{32}$ in. × $\frac{25}{32}$ in., thus offering circuit designers a wide variety of space-saving units.

Although the capacitors are of such small size, they retain the superior characteristics of larger polystyrene capacitors:

Insulation resistance: 750,000 MΩ or 250,000 ΩF whichever is the smaller.

Power Factor: not greater than 0·001 at 1 kc/s.

REC 105 *for further details.*

Stac-Racs

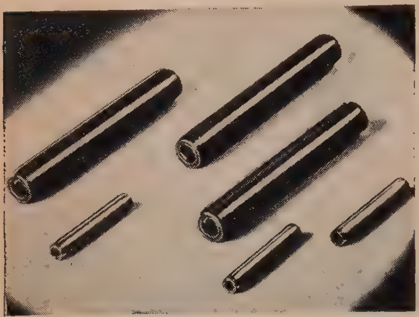
The Welconstruct Co. Ltd. has introduced a new range of workpan and tote pan racks. These consist of separate stacking units each 9 in. high which can be securely built up to make storage racks of any size.

The advantages of the system are said to be that the racks can be built to any height; they can be readily changed around or extended to meet varying requirements; they can be moved by hand or truck; all pans are readily accessible and removable; the range is designed to take standard 12 in., 18 in. and 24 in. galvanized tote pans; the pans can be stored horizontally or tilted forward.

REC 106 *for further details.*

Spirol Spring Pins

The Lewis Spring Co. Ltd. will shortly introduce a range of Spirol spring pins with chamfered lead in, specially designed for speedy assemblies.



Spirol spring pins.

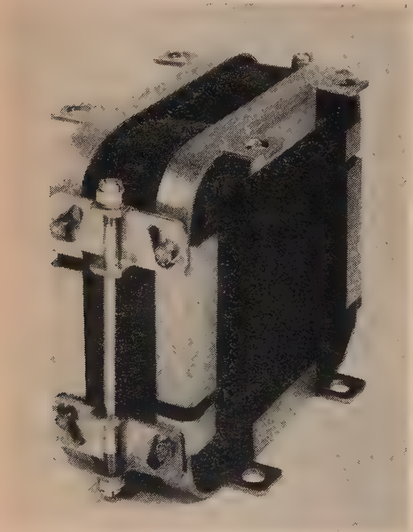
These pins absorb shock and vibration, provide uniform flexing and compression, and allow wide hole tolerances. They can be removed as easily as they can be inserted, without damaging holes, and can be re-used.

The size range is $\frac{1}{32}$ to $\frac{3}{4}$ in. diam. by $\frac{1}{8}$ to 4 in. long, and they are made from spirally-wound carbon-chrome stainless, and nickel stainless strip steels.

REC 107 *for further details.*

C-core Transformer Clamp

The approved method of assembly of C-cores in shell-type transformers is to use a steel band which is applied with a known tension, and then solder-sealed. Another method commonly used for larger C-cores employs a screw-type band, but whichever method is adopted, clamping frames must be used to accommodate a terminal board and also to provide mounting facilities.



C-core Transformer Clamp.

M.K.S. Nucleonics Ltd. has patented a dual-purpose clamping frame having significant advantages over those types at present available which are claimed to be as follows:

(*a*) Elimination of the banding of the cores.
(*b*) Automatic location and lining up of the C-cores.
(*c*) Low assembly costs.
(*d*) Small number of separate components.
(*e*) Competitive prices.

For horizontal mounting with Inter-Service fixing centres, an inexpensive and simple adaptor plate is available, as are coil shrouding plates.

It is claimed that this dual-purpose frame is a major contribution in the field of C-cores accessories, and in addition has its uses with the usual laminated cores. Prototypes have been exhaustively tested and production quantities will be available in the near future for the standard range of C-cores and for other sizes.

REC 108 *for further details.*

Porous Plastic

A new porous plastic—Vyon—which is produced from high-density polyethylene of the Ziegler type, is now being manufactured by Porous Plastics Ltd.

Vyon is said to have excellent permeability which, although uniform, can be controlled in manufacture to suit individual applications. It has apparently been proved most successful in the industrial, scientific and medical fields and has unlimited potential uses. At present, it is being supplied to Canada and several European countries, notably Germany and Italy, and is now made more widely available for world export.

The plastic has many advantages, being light, flexible and very strong; it is easily machined and fabricated; it is hygienic and when used for filtering acids it will not corrode.

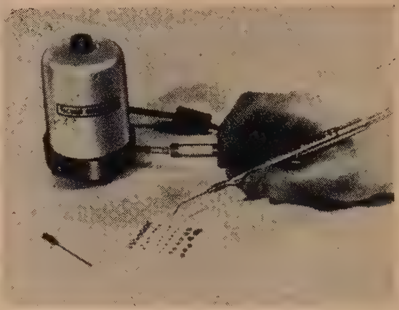
Some of its applications are in air and liquid filtration, air fluidized powder conveying, powder aeration pads for silos and bunkers, filters and silencers on pneumatic equipment, electrolytic diaphragms and deionising equipment. The plastic also acts as a useful filter material and has proved very successful in atomic energy plants in Great Britain. It is free from detachable fibres and its smooth surfaces make mechanical cleaning easy. In the majority of filtration applications it can be used unsupported. It is inexpensive, and is easily transported and fitted into plant and equipment.

REC 109 *for further details.*

Vacuum Tweezers

L. E. Simmonds Ltd., have been appointed sole concessionaires in the United Kingdom for the vacuum tweezer system V-100 made by The Vacuum Tweezer Co., New Jersey, U.S.A.

The system, which is portable and self-contained, operates from an a.c. mains supply and consists of a patented electromagnetic vacuum generator and a vacuum pencil with stainless steel pick-up tip. No larger than a tea cup, the generator is provided with an adjustable pressure control. The vacuum pencil is similar in size to a propelling pencil, and is connected to the generator by flexible tubing which incorporates a dirt filter. Various shapes and sizes of pick-up tip are provided.



Vacuum tweezer system.

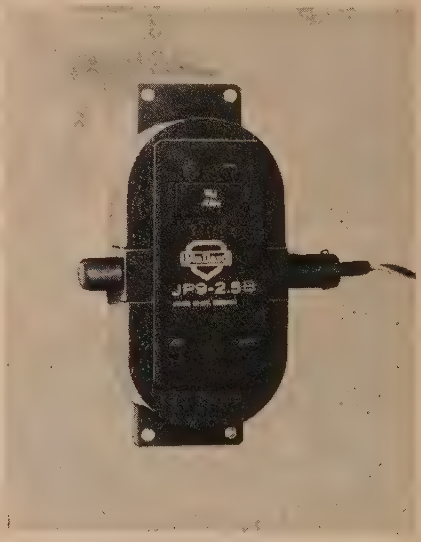
Operation is easier, and less likely to damage the component being picked up, than any mechanical handling arrangement. To hold a component the operator simply touches its surface with the pick-up tip of the pencil, at the same time covering a small opening in the pencil body to maintain vacuum pressure. Uncovering the opening will release the pressure and the component.

The system ensures faster handling of even the most delicate parts without damage and is ideal for instrument, electronic, laboratory and production use.

REC 110 *for further details.*

X-band Magnetron

A new low-power pulsed magnetron, Type JP9-2·5B, is now available from Mullard Ltd. This has been developed for use in



X-band magnetron.

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inexpensive X-band radar equipments. It is designed to operate within the frequency band 9·19 Gc/s to 9·32 Gc/s and is suitable for connection to WG16 waveguides.

Under typical operating conditions, (anode pulse voltage of 3·4 kV) the magnetron gives a peak power output of 3 kW with a pulse duration of 0·1 μs at a pulse repetition frequency of 2000 p/s. The limiting value for mean r.f. output power is 3W with a maximum pulse duration of 1·0 μs.

The heater requirements are 500 mA at 6·3 V.

The JP9-2·5B is in packaged construction and is designed for natural air cooling. Its weight is 2 lb. 4 oz. and its dimensions approximately 5¼ × 1⅓ × 2½ in.

REC 111 *for further details.*

Magnetic Plastic

Polypenco Ltd. has developed a new range of ferromagnetic plastic materials, marketed under the trade name Ferrotron. This is a non-memory, inductive core material and has already been successfully used as antenna couplers in conjunction with high-power transmitters in aircraft at intermittent service temperatures up to 350°C. It thus extends the operating temperature range of ferromagnetic materials considerably and, in addition, is unaffected by moisture and ageing.

The new material has a positive Q coefficient and constant magnetic permeability. High dielectric strength and low dielectric losses are coupled with a volume resistivity higher than 10^{10} Ω-cm. Ferrotron also possesses extremely high impact strength and resistance to vibrational stresses. It is expected that Ferrotron ferromagnetic materials will find many uses for tuning and loading cores and also for overwraps for delay lines.

The new material is available in flexible rod and tape form and in short segments that can be readily machined for prototype evaluation. Production quantities can be supplied as moulded parts, and a leaflet, BR-10, is available.

REC 112 *for further details.*

Co-axial Relay

Designed in conjunction with the B.B.C., the new A 10 high-power coaxial relay is now available from B. & R. Relays Ltd.

The A 10 has been designed to handle 1 kW of r.f. power using Type "C" or Type "N" connectors. The contacts are of the single change-over type and are of silver palladium. Coils are suitable for voltages up to 50 V d.c. and the characteristic impedance is 50 Ω. The v.s.w.r. is less than 1·09 and the cross talk is 63 dB down—both at 65 Mc/s. The A 10 is at present being used as an aerial change-over switch at unattended v.h.f. satellite transmitters.

REC 113 *for further details.*

Variable Voltage Magnetron

A new magnetron, the Eimac Type X747, is now available through Walmore Electronics Ltd. It is said to be unique in that the frequency can be varied over the frequency range from 450 to 1150 Mc/s by varying the voltage from 700 to 1950 V. The power output is a minimum of 50 mW over this range. (Powers up to 5 W can be obtained for narrow band operation). The tuning characteristic is extremely linear and should make the valve very attractive in frequency-swept oscillators.

Variable voltage magnetron.

The X747 is of ceramic/metal construction and is "packaged" in it's magnet assembly. A specially designed cathode is used to realize good operating life.

REC 114 *for further details.*

8½-in. Monitor Tube

A new high quality 8½ in. monitor tube, Type AW21-10 for industrial television channels has been introduced by Mullard Ltd.

To secure high resolution, the tube has been given a deflection angle of 90°, but the cone contour has been specially shaped and the neck made narrow so that it may be used with standard 110° scanning coils. This combination of 110° coils on a 90° tube reduces deflection defocusing, and allows the use of currently available scanning coils in place of the obsolescent 90° type.

8½ in. Monitor tube.

An additional feature of the tube is its guaranteed light output of 100 ft-lamberts at a cathode current of 100 μA. The tube is electrostatically focused and uses a medium persistence phosphor giving a white fluorescence. Under typical operating conditions a first anode voltage of 600 V and a final anode voltage of 13·5 kV are required. The heater current is 300 mA at 6·3 V and a B8H base is used.

Application work has been carried out on switchable 405/625 line and field timebase circuits suitable for use with the AW21-10 and full details are available on request.

REC 115 *for further details.*

Ultra-violet Detector Heads

These units have been developed by Elcontrol Ltd. to meet the growing demand for a low-cost ultra-violet detection head which will allow the sometimes useful advantages of ultra violet detection of flames to be utilized where necessary.

These heads, involving as they do extra stages of amplification, are necessarily more expensive than the infra-red flame-electrode, and visible-light heads pioneered in the United Kingdom by Elcontrol and developed over the years into the FSM type of flicker or low frequency a.c.-tuned detection circuitry.

These heads utilize easily available replacement photocells in order to avoid servicing delays and cut down expense. They may be connected to any of the Standard FSMI, FSM5, 6 series units which include programming and other facilities and also may be utilized with the modular series of flame relays (FR5 & 6) and control units (CU1).

They are alternative to the VH31P, VH101P, VH102, FE3, FE2B, types of visible light, infra-red and conductivity detectors all of which we find are in constant use and demand to meet the varied types of fuels, burners, burner position and combustion condition. The availability of these new heads may enable some problems of flame discrimination to be solved more easily.

Both heads consist of a special ultra-violet photo-sensitive cell having a relatively high temperature stability and housed in a cast-aluminium head with an asbestos gasketted cover. The photo-cell has an estimated life of two years. Attachment to the sighting tube is by a captive 2 in. B.S.P. nut and consequently interchangeable with many standard detection heads.

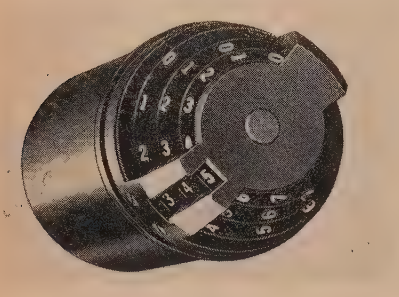
The Type UV1 head is connected *via* a standard 6 ft armoured 4-core cable to the control unit terminating in a 4-pin Cinch plug. The Type UV2 head is connected with 2 cables both 6 ft long and in armoured flexible conduit, one, the detection cable terminating in a 4-pin cinch plug and two, the power cable running back and looped in to the standard 240 V mains supply in the FSM control box.

The UV1 head is for use on flames which have a large amount of modulated ultra violet and for occasional use in all single burner installations while the UV2 is for use where greater discrimination is required such as on multi-burner installations and on very steady flames which have little natural flicker of emitted ultra-violet light.

REC 116 *for further details.*

Co-axial Switch Units

Two co-axial switch units, manufactured by Gertsch Products Inc., measure only 2½ in. diam. and provide 3 to 30 discrete circuits. These are now available from The Wayne Kerr Laboratories Ltd.



Subminiature coaxial switch unit.

The sub-miniature switches, designated CSU-1 and CSU-1A, are designed for the remote electrical control of decade or binary information. Within each unit are three or four switches with up to twelve positions, all of which are controlled by the concentric dial arrangement.

Both units have bold, in-line readout and rugged gear-driven switch assemblies and both are available for servo ring or flange mounting. Connections to these switches are made by a sub-miniature connector at the rear.

Model CSU-1 is certified to meet all applicable military specifications and will operate under severe environmental conditions.

REC 117 *for further details.*

Subminiature High-speed Switching Diode

The GEX71, a new germanium gold-bonded diode from G.E.C. Semiconductor Division is now available in sample quantities. This diode is mounted in a sub-miniature, all-glass case and is characterized by a very fast transient response, making it particularly suitable for use in high-speed switching circuits.

An advance data sheet on the diode is available, but brief information has been given as follows:

Maximum continuous reverse voltage rating: 10 V; Maximum continuous forward current rating: 30 mA; Maximum peak (< 5 ms) forward current rating: 100 mA; Typical forward voltage drop at 10 mA: 0·45 V; Typical total recovered charge (10 mA forward current switched off with a reverse pulse of 5 V magnitude, with a rise time of less than 2 ns and at least 1 μs duration): 20 pC.

REC 118 *for further details.*

17-in. Studio Monitor Tube

The AW43-48 is a new Mullard Ltd. 17-in. television picture tube intended for use in precision television studio picture monitors. The tube uses electrostatic focusing and magnetic deflection, and the scanning angle is 70°.

Under typical operating conditions, a first anode voltage of 300 V and a final anode voltage of 16 kV are required. The cut-off voltage (Vg) is from —30 to —70 V.

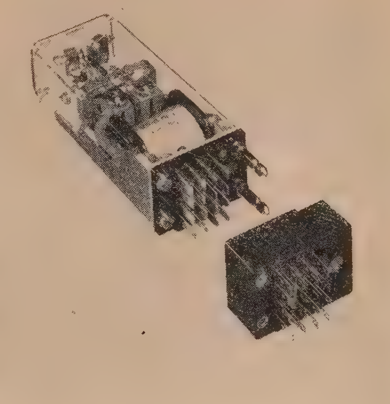
The AW43-48 will resolve a minimum of 650 lines based on a picture height of 273 mm, and measured at a brightness of 50 ft-lamberts, the focus voltage being adjusted to obtain the smallest roundest spot.

Apart from requiring a final anode voltage of 16 kV, the AW43-48 is electrically identical in its characteristics to the 14-in. tube type AW36-48, and has been introduced to meet the demand for a 17-in. precision monitor tube.

REC 119 *for further details.*

Siemens Polarized Relays

B. & R. Relays Ltd. are now able to offer in Great Britain a range of Siemens polarized relays. There are seven basic relays in the range, all of the Carpenter type, and covering both side and centre stable versions. The type numbers are from 63—69. They are available in plastic covers, as illustrated with plug-in base and socket or, if required, soldertag bases.



Siemens polarized relay.

REC 120 *for further details.*

Sound Level Indicator

A new model of their well-known sound level indicator is now available from Dawe Instruments Ltd., to provide quick and reliable readings of noise.

This fully transistorized Type 1408D instrument measures only 6×3×2¼ in. and weighs 14 oz. complete with dry batteries. The range of the instrument is from 64 to 110 dB, which is adequate to deal with most general and industrials applications. The built-in Rochelle-salt crystal microphone remains unaffected over the temperature range 0—45° (32—113°F).

REC 121 *for further details.*

Cubicle-type Fuse Switches

A range of compact "Cromwell" cubicle-type fuse switches is now being marketed by the G.E.C. Installation Equipment Group, in ratings of 150, 200, 300 and 400 A. These units are provided with all the attachments for building them into cubicle-type switchboards, but front covers are omitted, as G.E.C. believes that door-design should be a matter for the cubicle designer to establish.

Not only do the new units comply with all relevant B.S. and I.E.E. regulations, but they exceed the normally accepted performance standards.

Extra breaking capacity, extra shielding and extra safety are the three main features claimed for the units, and particular attention has been given to design to make connections with rod or strip, easy and quick. Neutral links can be fitted and, for additional safety, provision is made for a lock as an optional extra.

H.R.C. fuselinks (to B.S.88:1952) are used in "Cromwell" fuse switches, and a full specification is given in publication X 5464.

REC 122 *for further details.*

Co-axial Ratio Transformers

A range of coaxial ratio transformers—the CRT-1, 2, 3 and 4—with indicated ratio accuracies of from 0·01% to 0·001% between 50 and 10,000 c/s is now available from The Wayne Kerr Laboratories Ltd.

Common features of all four models, manufactured by Gertsch Products Inc., are high input impedance, terminal linearity of 0·001%, continuous resolution by means of in-line concentric dials, very low phase shift and an input inductance of 150 henrys.

Models CRT-1 and CRT-2 are designed specifically for restricted panel space—five units being easily mountable on a 3½×19 in. panel. The CRT-1 offers six-place digital readout (with a three-decade ratio transformer and a ten-turn interpolating potentiometer) whilst the CRT-2 is identical—

Co-axial ratio transformer.

except for a single-turn potentiometer—and provides five-place readout.

The CRT-3 and CRT-4 are subminiature types designed particularly for applications involving small panel areas with minimum depth and requiring units to meet military specifications. In spite of their small size, both the CRT-3 and 4 are claimed to have an accuracy of 0 001%, the CRT-3 giving five-place resolution and the CRT-4 six-place resolution.

The weight of the CRT-1, 2, 3 and 4 is approximately 7 lb. each.

REC 123 *for further details.*

Hughes Components

The intial success of the gold-bonded germanium and point-contact germanium devices manufactured by Hughes International (U.K.) Ltd. in the microminiature Hughes package has resulted in the following type approvals:

1. *CV*448: This is a sub-miniature version of the larger device which has previously been used in many point-contact positions in military and telecommunications equipment. This enables great saving of space over the previous designs and offers a real break-through where miniaturization is necessary.
2. *CV*7127: This is a new specification modelled around the Hughes gold-bonded diode, which covers most fields where a high-voltage gold-bonded device with a good hole storage and recovery characteristics is required.

In addition to these devices, the Company is now able to offer the following type approved components:

3. *CV*7041: This is a point-contact device meeting this specification, again in the sub-miniature package
4. *CV*7040: This is a sub-miniature silicon power-diode which is now freely available to the above CV number or to commercial specifications.

Hughes International has also introduced a range of 600 mW devices covering the popular IN645/7 range. Again these are in the sub-miniature package with a dumet heat sink which gives current ratings up to 400 mA with a p.i.v. range up to 800 V. These devices have been submitted for type approval to numbers CV7045, CV7046 and CV7013.

Hughes International is also now able to offer a range of zeners, voltage regulator diodes and cartridge rectifiers. Details of all these devices are available.

REC 124 *for further details.*

Delay Lines

Cossor Radar & Electronics Ltd. has extended its range of existing magnetostriction delay lines. Delay lines now available permit dynamic storage of pulse information for periods from 5 μs to 1·5 ms.

The lines consist basically of a nickel tube the ends of which are terminated in matched p.v.c. loads. Transducers, in the form of encapsulated ferrite-cored coils are threaded on to the nickel tube. When a pulse is applied to the input transducer, a magnetic field pulse is produced along the axis of the nickel tube. This in turn, promotes a strain pulse which is then propagated in both directions along the tube at a velocity equal to the speed of sound in nickel. As this strain pulse passes through the pick-off coil, an output pulse is generated. By varying the distance between the input and output transducers, adjustment of delay time can be made in circuit without disturbing the unit.

If required, a number of pick-off coils can be arranged along the delay line. In this way, several output pulses can be produced at discrete time intervals after the occurrence of a single input pulse. The number of output transducers that can be threaded on to a particular delay line is limited only by the physical length of the nickel tube and the longitudinal dimensions of the transducers. The lines thus find useful application in the production of binary coding and decoding sequences, selective gating systems, sequential calling devices, shift-registration, series to parallel and/or parallel to series converters.

Magnetostriction delay lines.

The complete delay lines can be supplied mounted in metal containers which, in addition to protecting the unit, provide a shield between the delay line and adjacent circuits. In addition to a number of standard ranges, the delay lines can be supplied with delay times adjusted to meet users' individual requirements.

REC 125 *for further details.*

Long-life Numerical Indicator Tube

Mullard Ltd. has developed a new cold-cathode numerical indicator tube, Type Z520M, with a greatly improved operating life. Its life expectancy is 30,000 h provided the display is changed from one numeral to another more than once in 100 hours, or 5,000 hours with continuous display of any single numeral. An additional feature is a built-in optical filter which ensures maximum readability of its numerals under all conditions likely to be met in practice—even direct sunlight.

The numerals are displayed in characters ⅝ in. (15·5 mm) high. The tube can be operated with a supply voltage of 170 V and a cathode current of 2 mA is recommended. Either a steady d.c. voltage or a negative pulse to the appropriate cathode for operation.

Numerical indicator tube.

The Z520M is similar both in structure and electrical characteristics to the earlier Z510M. Physical dimensions are: 28·5 mm (±1·5 mm) diam. by 25 mm (±1·5 mm) seated height. The tube has a B13B base.

REC 126 *for further details.*

Peak Reverse-voltage Silicon Rectifiers and Gas-filled Transformers

The first commercial series of high-current silicon rectifiers with a peak reverse voltage rating up to 1,000 V is available now from International General Electric of New York Ltd., the international marketing organization of U.S. General Electric.

These 100 A double-diffused high-voltage rectifiers are now in quantity production, and are available from stock in seven models. They may be obtained in either forward or reverse polarity, and the 1,000 V unit, with a transient voltage rating of 1300 V, will offer designers the opportunity to use one cell across a 440-V line rather than two or more cells with the consequential economies in assembly, circuit protection and system efficiency.

The new rectifier can be used to replace existing lower voltage silicon rectifier cells in the 50 to 100 A range. The hard solder construction of the units makes them resistant to thermal fatigue and enables them to perform reliably in applications where large temperature excursions are encountered. These rectifiers have been assigned JEDEC designations IN3289—IN3295 and differ by p.r.v. ratings which range from 200 V to 1,000 V.

REC 127 *for further details.*

Gas-filled Transformer. A newly designed gas-filled, sealed dry-type transformer marketed by International General Electric utilizes C_3F_8 (perfluoropropane) as an insulating/cooling medium. The gas is non-flammable, non-explosive and non-toxic and it is stated that it will not decompose even under extreme operating temperatures. Because of the superior insulating properties of the gas, impulse levels of the new transformers are higher than those of previous nitrogen-filled units. The perfluoropropane transformers are also smaller and lighter. They are available in ratings of 300 kVA and above, and 15 kV and below, and can be used as conventional transformers or as the transforming section in unit substation combinations.

REC 128 *for further details.*

Vacuo-junction Tubes

Best Electrics Ltd., a member of the A.C. Cosser Group of Companies, has developed a range of vacuo-junction tubes. These are specialized thermal converters which may be used as a.c.—d.c. transfer standards over a very wide range of frequencies.

The operation of these devices depends on the fundamental fact that, when two dissimilar metals are placed in contact, a small d.c. voltage is developed. Over a limited temperature range the magnitude of this "thermal e.m.f." is proportional to the junction temperature.

In the vacuo-junction tube, the junction is placed in thermal contact with a heating filament, which carries the current to be measured. The structure is contained in an evacuated glass envelope to minimize heat losses. Since the thermal e.m.f. developed is proportional to the junction temperature, it will now also be proportional, in turn, to the square of the heater current.

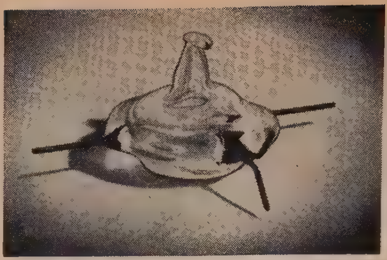
By measuring the thermal e.m.f. on a suitable calibrated millivoltmeter, an indication is given of the applied current. If the instrument is calibrated on d.c., then the same calibrations will hold, within very close limits, on a.c. Further, since the vacuo-junction measures the *heating* effect of the applied current, indicated readings will be true r.m.s. values, regardless of waveform. Within the frequency range 25 c/s—20 k/s, the Best standard pattern vacuo-junction is accurate to within 0·01% for all measurements.

Three patterns of Best vacuo-junctions permit between them accurate measurement over a frequency range extending from below 0·1 c/s to several hundred megacycles. Each pattern is available with a variety of heater ratings, the most sensitive being rated at 1 mA maximum heater current.

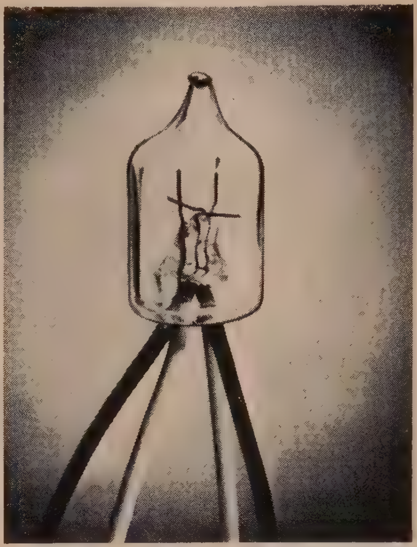
By arranging for one vacuo-junction to measure the current flowing in a circuit, and for another to measure the derived voltage of the same circuit, then the resultant thermal e.m.f. of the two junctions, when combined, will indicate the power consumed in the circuit.

In addition to the standard ranges, the Company can supply vacuo-junctions with characteristics arranged to meet users' own particular requirements.

Applications include: measurement of a.c. currents, voltages and power; measurement of aerial current in radio transmitters; measurement of effective current in loudspeakers; calibration of valve-voltmeters; indicators for signal generators; resonance indication in wavemeters; detection of stray h.f. currents. In addition, Best vacuo-junctions have been successfully used in an unsealed form as the sensing element in vacuum measuring equipment.



Two examples of vacuo-junction tubes.

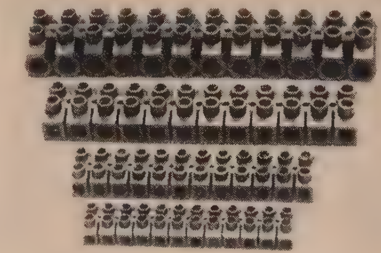


REC 129 *for further details.*

Polythene 12-way Terminal Blocks

Metway Electrical Industries Ltd. has begun marketing a range of flexible Polythene 12-way terminal blocks, which will be available in four sizes—5, 10, 20 and 30 A. The colour will be silver-grey and all metal parts will be plated.

These blocks are covered by a provisional patent, under the name "Captiveway", because once the screws are fixed, they become captive by means of three internal projections. The screws therefore remain secure even under vibration.



12-way terminal blocks.

REC 130 *for further details.*

Automatic Printed-circuit Drill

A new fully automatic printed-circuit drill, said to be the first of its type in the world specifically designed for fast and economical drilling of component fixing holes in printed-circuit boards, has been introduced by Ferranti Ltd. The new machine is already in limited quantity production.

As the size and capacity of transistorized digital computers continues to increase, production engineers are becoming more and more aware of the need to find short-cuts in producing the large number of printed-circuit boards required for these machines. The printed-circuit drill has been developed with quantity production in mind and in the knowledge that package production can also take up valuable time—particularly if a prototype machine or limited production run is planned. It is already being used successfully for drilling the hundreds of printed-circuit boards required for the Company's Atlas high-speed computer, and Argus process Control computer.

Basically, the machine consists of two drilling heads allowing either tandem or single spindle working; a hydraulically-operated co-ordinate table carrying the printed-circuit boards which is automatically moved to bring the board hole centres in turn below the drills; and a control system for the drilling action and table movement which enables the machine to work unattended except for loading and unloading.

The drilling table, which covers an area of 20 in. by 14 in., is moved parallel with or at right angles to the front of the machine by two hydraulic jacks. Accurate positioning of hole centres under the drills is carried out in two contiguous stages. Firstly, rough positioning is achieved by the use of a perforated template and photo-electric cell. Secondly, accurate positioning is produced by a mechanical indexing system using the meshing of a half nut and precision rack. A positional accuracy of ±0·001 in. can be obtained and repeatability is within 0·001 in.

Drilling is carried out to a grid system, the holes being drilled in a systematic pattern of rows and columns. The basic spacing between rows of the grid system is determined by the pitch of the thread of the precision rack associated with row alignment. A typical pitch is 20 threads per inch giving a spacing between rows of 0·050 in. or multiples thereof. A similar precision rack is used for column alignment. It should be noted that the basic spacing need not be the same for rows and columns.

The perforated template is mounted on an extension of the drilling table and whenever a hole in the drilling area of the template coincides with the light beam, the photo-electric cell is stimulated and provides a signal to the machine's control system. This signal initiates: (1) The cut-off of the oil flow to the hydraulic jacks stopping the drilling table; (2) The application of oil to the half-nut mechanism to mesh the half nut with the precision rack, thereby accurately locating the table and locking it in position;

(3) The drilling action by switching electrical power to the drills.

Automatic printed-circuit drill.

On completion of the drilling action, a signal from the drilling head is fed to the control system to release the half nut from the rack and to re-start the flow of oil to the jacks which move the table. This process is then repeated for the next hole in the template.

As mentioned previously the pattern of holes is systematically drilled row by row. When a row is completed, the drilling table moves to bring the adjacent row into line with the drilling heads. Movement of the drilling table to bring the next row into line is controlled by two columns of row marker holes in the template. Each row of the drilling pattern has an associated row marker hole. These holes stimulate the photoelectric cell and the resulting signal to the control system causes the table to move up to the next row and along that row. When the last hole is drilled, the drilling table returns to its start position and stops.

The machine can accommodate a single stack—up to ⅜ in. deep—of one or more printed-circuit boards with dimensions of up to 12½ in. by 18 in. with maximum drilling dimensions of 11½ in. by 17½ in. Alternatively, it can accommodate two stacks of identical boards for simultaneous drilling—each stack up to ⅜ in. deep and one or more boards per stack—each with dimensions up to 12½ in. by 8½ in. with maximum drilling dimensions per board of 11½ in. by 7¼ in.

The rate of output of completed boards is dependent on the pattern of holes to be drilled and the number and thickness of boards forming the stack. For example, two stacks of four boards for the Argus computer requiring 288 holes per board, are completely holed in 14½ minutes, i.e. an average time of 108 seconds per board including loading and unloading. These boards are approximately 5½ in. by 7½ in. by $\frac{1}{16}$ in.

The machine, which weighs about 18 cwt. is suitable for use from a 3-phase a.c. mains supply, the loading being approximately 1·5 kVA. Installation is relatively simple as no special levelling is required. The area of the base casting is 49 in. by 42 in. and the height from floor to table is 41 in. Chuck capacity is 0—$\frac{5}{32}$ in. and the maximum drilling thickness in synthetic resin bonded paper is ⅜ in. The Dumore Series 20 drill heads incorporate a series type motor having a chuck on one end of the shaft and a 3-blade vane type compressor on the other end which provides the necessary compressed air for feed thrust.

The speed of the spindle is automatically governed by the drill size and the work material. The larger drills offer more rotational resistance which slows down the series motor, thus providing automatically the proper speed for a given drill. Speed is governed primarily by the air pressure regulator setting, the higher pressures providing more thrust and therefore a higher feed rate. The proper air pressure regulator setting for a given drill size will automatically provide the correct number of r.p.m. (2,500—7,500) and feed rate.

An important feature of the machine is that the operating and control mechanisms are completely shrouded against the ingress of drilling swarf. Maintenance is confined to the occasional topping up of the hydraulic oil reservoir about once every six months.

REC 131 *for further details.*

Double-gun Helical p.d.a. Cathode-ray Tube

The M-O Valve Co. Ltd., has added a new double-gun helical p.d.a. cathode-ray tube to its already extensive range. It is a 10 cm diam. tube, Type 1000F, for use in general-purpose oscilloscopes in which two independent signals are displayed on a common time base.

Deflection sensitivity in the x direction is 24 V/cm and in the y direction 14 V/cm with a gun voltage of 1·2 kV and a final anode potential of 4 kV. The line width is approximately 0·4 mm.

The two guns scan a common window of 6·3 cm × 6·3 cm. Side pin connections to the deflector plates contribute to low input capacitance and the overall length, excluding base pins, is 34·8 cm ±0·5 cm.

Double-gun helical p.d.a. cathode-ray tube.

REC 132 *for further details.*

Transistor Clips

The Lewis Spring Co. Ltd. has increased its range of component parts for the Electronic Industry by the addition of a series of transistor clips to suit cylindrical transistors of 5·6 mm/5·9 mm (reference number E. 7522), 4·3 mm/4·6 mm (reference number E. 7523) and 8·5 mm/9·1 mm (reference number E. 7840), (registered number 895360) for fixing horizontally to printed-circuit boards.

Transistor clips.

The clips are manufactured from beryllium copper and application has been made for Type Approval.

Further developments are in hand for a range of flute fixing transistor clips in spring steel, to suit diameters of 5 mm, 6 mm and 9 mm, for "close-to-the-board" assemblies. The Registered Design number is 901065. In addition, a Unistor clip (Registered number applied for) suitable for the STC.460 Unistor of 0·360 in. diam. is being developed.

All this clips may be polythene coated if required.

REC 133 *for further details.*

Metal-oxide Film Resistors

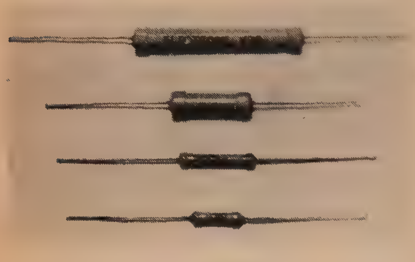
Electrosil Ltd. has recently been formed to manufacture and sell a range of metal oxide film resistors originally developed in the U.S.A. by Corning Glass Works.

Experience gained in glass techniques has enabled the development of a superior range of resistors which has exceptional long-term stability and is virtually unaffected by soldering heats or chemical and mechanical attack. The fusing process used for producing Electrosil resistors is one which makes the resistive element *harder* than the optical-quality glass base itself. Additionally, glass hermetically-sealed capacitors, of exceptionally high rating and stability, together with a range of adjustable trimmers are available.

Of interest is the Electrosil "Foterceram" grid board which enables engineers to produce, within a few minutes, high-quality "printed-wiring" circuits for prototype work.

Costing no more than currently available types, Electrosil are able to offer a range of resistors of better than Grade 1 performance, which has led to the introduction of a new Defence Specification (DEF 5114).

The N-type resistor is of metal-oxide film on optical quality glass construction. Life testing of 1500 resistors over a period of three and a half years at loadings up to 140% of rated wattage showed resistance changes of less than 1%. Failure tests over this period revealed no catastrophic failures and assuming a ±3% resistance change as a failure, the actual rate was less than 0·000083 per 1000 resistors.



N-type resistors.

With a noise level of less than 0·015 µV/V coupled with outstanding long-term stability, N-type resistors offer a low priced answer to designers of all types of equipment.

REC 134 *for further details.*

Zener Diodes

The SZA/C series of silicon zener diodes, formerly of ±10% tolerance, now has a nominal tolerance of ±5% and stretches from 5·6 V to 33 V. The maximum mean power dissipation at 40°C is 1·5 W and the diodes are enclosed in a double-ended case with wire leads and a threaded base.

The diodes are numbered SZ56A to SZ91A and SZ10C to SZ33C with nominal zener voltages of 5·6 V to 33 V, graded according to the international preferred values of the 10% increment series. The typical temperature coefficient of breakdown voltage varies between +0·02% per °C for the SZ56A to +0·09% per °C for the SZ33C.

A comprehensive provisional data sheet is available on request.

REC 135 *for further details.*

Closed-entry Test Jack

The Sealectro Corporation has announced a closed-entry test jack utilizing the Sealectro "Press Fit" mounting principle. The SKT-34 test jack is designed to receive a 0·032 in. diam. probe, to a depth of 0·200 in. max. The closed entry assures perfect alignment of the probe in test operations and the contacts are beryllium copper, designed for maximum service life.

Closed entry test jack.

The SKT-34 provides a double-turret stud on the reverse side of the chassis for termination of associated circuitry. The p.t.f.e. body is 0·148 in. diam., with a 0·172 in. diam. above-the-chassis shoulder.

The "Press-Fit" design of this product allows fast, positive insertion through a hole in the metal chassis by merely pressing into place.

REC 136 *for further details.*

Test Jack

The Sealectro Corporation has made available a new p.t.f.e. insulated test jack designated as Type SKT-37.

The component receives a 0·090 in. diam. probe, 0·140 in. long. The overall diameter, above the chassis, is 0·218 in. while overall height, including mounting shoulder and soldering stud, is 0·340 in. The test jack has a 0·170 in. diam. body for the through-chassis mounting.

The electrical contact for the test probe is of beryllium copper, providing positive, low-resistance conductivity for accurate take-off measurements. The body is made of a solid piece of machined, virgin p.t.f.e. permitting the usual Sealectro "Press-Fit" installation.

Sealectro test jack.

REC 137 *for further details.*

New Exide Battery

An improved type of 1½ V cell, similar in shape and size to the familiar "penlight" and known as the T.4 has been introduced by Chloride Batteries Ltd. Measuring only 9/16 in. diam. × 2 in. high, the T.4 is especially suitable for use in transistor sets which require batteries of the "penlight" size. Since the characteristics of the normal T.5 or DL.25 type of cell do not meet completely the requirements of a radio set, the new cell should be a welcome addition to the Exide/Drydex range.

REC 138 *for further details.*

Dielectric Polystyrene

Polypenco Ltd., announce the availability of a new dielectric material for the Electronic and Electro-mechanical industries.

Known as Polypenco Q-200.5, this product is a cross-linked polystyrene having excellent rigidity, and the ability to resist deformation under load and high impact strength. It has negligible water absorption, is transparent and may be used permanently at temperatures of 100°C. For short periods of time the material is form stable up to temperatures as high as 204°C.

The material has outstanding properties as a u.h.f. insulator up to 10,000 Mc. The loss tangent compares favourably with that of polytetrafluoroethylene and polythene and both volume and surface resistivities are better than p.t.f.e. at low frequencies. The dielectric constant is subject to little variation over the widest frequency range.

Readily machined on orthodox metal-working equipment Q-200.5 cross-linked polystyrene can be supplied from stock in round rod form 3/32 in. to 3 in. diam. and in plate form 1/8 to 1 in, thick.

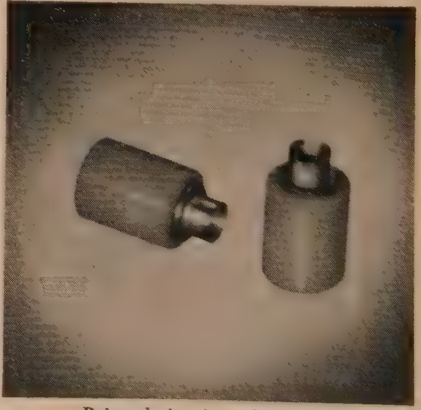
REC 139 *for further details.*

Printed Circuit Jack Socket

A new printed circuit receptacle jack Type SKT-111PC, has been designed by the Sealectro Corporation. It features a p.t.f.e. body and spinover mounting which enables vertical mounting on the printed circuit board.

The component is only 0·381 in. in height before spin-over of mounting stud. It is designed to accept a standard 0·080 in. diam. probe × 0·250 in. length max. The overall diameter of the body is 0·218 in., and the mounting is rigid and electrically sound due to the fact that the printed-circuit board is compressed between a metal shoulder and the spin-over.

The jack is said to be suited for any printed-circuit or printed-wiring applications which incorporate test points at various positions within the circuit, or again, in modular construction in which additional external connections must be made to associated circuitry.



Printed circuit jack socket.

REC 140 *for further details.*

NEW AMERICAN COMPONENTS

These products are available only from America or from European agencies and there is likely to be some delay in providing readers with further information.

Raytheon Company

Silent Potentiometer: This is sealed in a transistor case, and is the newest and smallest model in Raytheon's growing line of Raysistor devices. Designated the CK1114, it is designed for either a switch, relay or potentiometer application in circuits requiring minimal space and power.

The component uses a tiny incandescent bulb as the control element and a miniature photosensitive resistor as the signal element. It can be driven with the low power of only 25 mW at 1 V and, when illuminated by this power, the photosensitive cell changes its resistance value from 2 × 10⁸ Ω to 460 Ω. Designed to withstand up to 60 V d.c. across its terminals, the signal circuit will dissipate up to 50 mW.

Either a.c. or d.c. supplies can be used to drive the control circuit and similarly, the signal circuit will switch or vary either an a.c. or d.c. signal.

The unit is 0·370 in. diam., 0·260 in. high and weighs 0·4 oz., similar in size to TO-5 transistor case.

REC 141 *for further details.*

Shock-resistant Rectifier Tube: The rectifier, Type 5R4WGB, is designed for high-current, high peak-inverse-voltage power supplies. It is capable of supplying 840 V at 165 mA or 730 V at 275 mA, and is a Military Standard 200E preferred type used in power supplies for airborne, mobile and shipboard radars and communications equipment.

The tube's maximum peak-inverse-voltage rating is 2,900 V at an altitude of 35,000 ft and 1,850 V at 60,000 ft. Construction features include a foam rubber-lined base to meet severe shock and a T-14 hard glass bulb for high temperature resistance and freedom from gases. Maximum outside dimensions of the five-pin tube are 5¾ in. by 1 $\frac{1}{16}$ in.

REC 142 *for further details.*

Germanium Diode Quads: Fifty-four diode quads, designed as bridge rectifiers, ring modulators, voltage multipliers or series strings, are available in six package styles. The units consist of four matched, hermetically-sealed germanium gold-bonded diodes. The devices have a 1%, 2·5% and 5% degree of forward match at 4 mA, a p.i.v. rating for each diode of 35, 75 or 100 V, and a maximum inverse current of 10 or 20 μA at − 10 V.

All assemblies are designed for applications where low shunt capacitance, absence of heater voltage and resistance to changes in humidity and temperature are required. The germanium gold-bonded diodes incorporated in the sub-circuits are tested for hysteresis, drift and flutter and are repeatedly cycled in humid ambients and in temperatures ranging from −55°C to +100°C.

REC 143 *for further details.*

Subminiature Germanium Transistors: Double-ended subminiature germanium transistors for computer and switching and general purpose radio and audio frequency applications are now available.

There are 20 variations in the new range and their actual size is 0·130 in. by 0·130 in. or 21 times smaller than their TO-5 equivalents. Their temperature range is −65°C to +85°C.

Mounting possibilities for the double-ended subminiatures include single and multiple-board configurations, feed-through construction, welded assemblies and special assembly modifications such as jump-wiring and isolating inputs from outputs.

REC 144 *for further details.*

Fast-switching Silicon Transistors: These have been designed for servo controls, d.c. control circuits and power switching of up to 4 W.

Designed to meet MIL-S-19500B requirements, the four *n-p-n* types are packaged in a welded, hermetically-sealed TO-5 case capable of withstanding storage temperatures as high as 200°C.

The 2N497 and 2N656 are 60-V devices and the 2N498 and 2N657 are 100-V devices.

REC 145 *for further details.*

Industrial Electron Tubes: A line of industrial electron tubes designed for use in measurement test equipment, instrumentation and similar applications, and consisting of the six types, 7728—7733, was formerly manufactured by CBS Electronics. Manufacturing and future expansion of the line will be conducted by Raytheon.

The tubes feature precisely made and fitted parts in stronger structures for lower noise and microphonism, and increased life test controls from 500 to 1,000 h. They incorporate gold-plated pins and a rugged coil heater that adds both electrical and mechanical strength, decreasing heater-cathode leakage and hum and virtually eliminating the chance of burn-outs. Careful selection of cathode sleeve material resists the formation of interface impedance, assuring more stable electrical characteristics and longer life.

REC 146 *for further details.*

Multiple Diode for Logic Circuit Applications: This space saving device, consisting of three diodes packaged in a single TO-5 case, incorporates simplified wiring designed for high-speed operation. Reliability is maintained by the welded, hermetically-sealed package, and is increased further because the four external leads are inserted in the base in one operation instead of four separate operations. Storage temperature range of the unit is −40°C to +85°C.

REC 147 *for further details.*

Germanium Epitaxial Mesa Transistors: Nine germanium epitaxial mesa transistors have been designed for use in high-speed logic circuits. These are said to exhibit a lower saturation voltage and storage time than ordinary mesa transistors and incorporate high-temperature materials to increase reliability. They have a saturation voltage at less than 0·2 V at 10 mA with a gain bandwidth of 600 Mc. Operating temperature range is −65°C to +100°C.

The new units are designated Types 2N828, 2N705, 2N705A, 2N710, 7N710A 2N711, 2N711A, 2N781 and 2N782.

REC 148 *for further details.*

* * *

JFD Electronics Corporation

New Combination of Platings for Trimmers: The Components Division has developed a new combination of platings for all metal parts on JFD trimmer capacitors, l.c. tuners and metallized inductors.

For several years, JFD has employed JFD alloy plate and gold overplate on all metal parts supplied on its capacitor and inductor lines, in order to meet the 50 h military salt spray requirements and to provide adequate r.f. conductivity where necessary. The new plating will withstand a 64 h salt spray test as per military specifications and is, therefore, superior in this regard to the older plating. Gold overplating was eliminated as chromate conversion coating over silver plating was found to be superior to the gold in preventing of tarnish The plating provides smoother tuning action between the threads of the adjust screws and the threaded bushings, resulting in slightly longer adjust life of the components.

REC 149 *for further details.*

★ ★ ★

Semi-Elements Inc.

Laser Material: Production has commenced on Barium Fluoride doped with Uranium which has an output wave length of 26,000 Å making it an excellent infra-red laser material. This is compared with Calcium Fluoride doped with Uranium which has an output wave length of 25,000 Å, also in the infra-red. Further investigation is being carried out on doping Barium Fluoride and Calcium Fluoride with other materials.

REC 150 *for further details.*

★ ★ ★

Webber Manufacturing Co. Inc.

Portable Environmental Chamber: A new portable environmental chamber, Model W—2—100+200, that moves to the item requiring a test, is designed for use on components, parts and products undergoing vibration or shaker tests, and for other applications where it is impractical to bring the item to the chamber.

A 19 in. diam. insulated dome, connected to the mobile chamber with two flexible insulated hoses, fits over the product. Temperature range is from −100°F to +200°F, with a pull down from maximum to minimum temperatures in 45 min. Internal air circulation assures zero stratification throughout the entire range.

The Chamber is available with other temperature ranges and hood styles, with either air or water cooled refrigeration units.

REC 151 *for further details.*

★ ★ ★

Radio Corporation of America

Broadcast Microphone: A new microphone has been introduced, with a built-in amplifier and earphone jack, for use during remote broadcast pickups. In use, the compact unit attaches by cable to a telephone line for feeding the programme to the studio. A miniature earphone plug enables the announcer both to hear telephoned cues from the studio and to monitor the microphone's output.

The microphone carries the transistorized amplifier and battery power supply within its thin, cylindrical shape, and provides full-range frequency response with very low distortion. It weighs less than one pound and can be stowed in a small carrying case for transport.

REC 152 *for further details.*

MANUFACTURERS' PUBLICATIONS

Semiconductors Device Guide

A new and revised edition of the G.E.C. Semiconductor Division's *Device Guide* is now available.

This new edition contains information on many newly introduced devices including the new subminiature high-speed switching diode GEX71, the widened range of medium power zener diodes (SZA/C series) and new high-power silicon-controlled rectifiers. In addition to electrical and mechanical specifications of the wide range of G.E.C. semiconductor devices, the new publication includes a list of CV types supplied by the Division with their nearest commercial equivalents and a commercial comparative table.

REC 153 *for further details.*

Precision-bore Glass Tubing

Details of the manufacture, and some of the applications, of "Pyrex" precision-bore tubing are contained in the October issue of *Pyrex Glass*, which is a bi-monthly technical bulletin. The applications which are described in the October issue are high-vacuum reference gauging, manometers, and the manufacture of electronic tubes for television, scientific and industrial uses.

REC 154 *for further details.*

High Purity Metals

The latest series of data sheets issued by Johnson, Matthey & Co. Ltd., covers their range of high purity metals. Information is given on 38 metals including noble, rare earth and certain base and rarer metals. The general properties of each element are tabulated and details are given of the forms of current production.

REC 155 *for further details.*

Neon Indicator Lamps

Described in a four-page leaflet issued by Walmore Electronics Ltd., the neon indicator units Types SGF and SGFF can be used for any voltage exceeding 200 V a.c. and are said to have a very long life of over 500 h. The lamp, resistor and holder are combined to form a compact unit which is locked in a mounting hole by three stainless steel springs. The lamp is protected by a plastic cap, Type SGF with a spheric front and Type SGFF with a flat front, that permits the engraving of signs. The lamps are manufactured in six different colours.

REC 156 *for further details.*

Coaxial Connector Catalogue

A catalogue has been issued by the Electronics Division of Greenpar Engineering Ltd., This Company has been formed to undertake the complete manufacturing, in its own works, of all components listed in this catalogue, excepting the parts of dielectrics and gaskets. Facilities are available for the manufacture of special types of coaxial connectors to customers' individual requirements. The Company is fully A.I.D. and A.R.B. approved.

A simple system of coding is employed throughout the catalogue. The prefix letters GE- (Greenpar Engineering) are followed by five figures. The first digit indicates the series of connectors, the second and third digit the impedance in ohms, and the last two digits indicate the serial number of the type within the series.

All the American type coaxial connectors with a U.S. Military Number listed in the catalogue are manufactured strictly in accordance with the latest U.S. Military drawings and specifications and are fully interchangeable with those of American or British manufacture where the U.S. Military Number is quoted. Interchangeability is assured by the use of master gauges, made in accordance with U.S. Military standards.

The materials used throughout all series are machined brass shells, silver plated; p.t.f.e. insulation, silicone rubber or neoprene gaskets, beryllium bronze or silver plated brass contacts, conforming either to the American standard specifications or the British equivalent standard specifications. It is intended that the connectors in the Series BNC and C shall be submitted for inter-service quality approval and subsequently, when the Ministry of Supply schedule of Series BNC and C connectors is issued, inter-service type approval.

Special size cable entry parts can be supplied to the plugs and jacks, to enable all the connectors to be used with other r.f. cables not listed.

All connectors can be A.I.D. or A.R.B. released, either against the Greenpar Engineering Code Number or the purchaser's own drawing number, but not against the U.S. Military number.

Cross-reference tables are provided, to assist in the quick selection of a connector, either by the U.S. Military Number or the Greenpar Engineering Code Number.

REC 157 *for further details.*

Solid-state Circuit Elements

A six-page leaflet describing the complete range of solid-state circuit elements which is now available from the Telephone Manufacturing Co. Ltd. The leaflet contains a general introduction to solid-state elements as well as comprehensive technical specifications and dimension diagrams of the modulator SM10, amplifier SA10, oscillator SO11 and demodulator SD11.

REC 158 *for further details.*

MANUFACTURERS' PUBLICATIONS

Continued from previous page

New Range of Transistors

A new range of silicon *p-n-p* junction transistors has been introduced by the Brush Crystal Co. Ltd. Described in a technical bulletin, the range, known as the OC700 series, consists of five transistors designed to meet the needs of most low-frequency applications. These transistors can be used in many applications for which germanium transistors were previously necessary.

REC 159 *for further details.*

Silicon Variable-capacity Diode

A leaflet describing a silicon variable-capacity diode, an extremely small, light-weight device for use in radio and television receivers for v.h.f. tuning, automatic frequency-control circuits, frequency modulators, band-pass filters and remote-control tuning, has recently been issued by the Brush Crystal Co. Ltd. This new device has been designed to take the place of conventional trimmers and even gang condensers.

REC 160 *for further details.*

Elapsed Time Indicators

Cass & Philip Ltd., has recently issued a four-page leaflet which describes their new type elapsed time indicators. The indicators, which are of particular interest to engineers concerned with problems involving wide voltage fluctuations, operate by a 6 V d.c. supply at 30 mA ± 10% instantaneous, and the voltage stabilizing system, based on a Zener diode, ensures that this voltage is maintained to the operating coil within tolerances, in spite of wide fluctuations in the supply voltage.

REC 161 *for further details.*

News from Londex

The August edition of *News from Londex* features electronic timers; a miniature pressure switch Type PS/MIN; inching push buttons; miniature relays Series 101; annunciator units Type SIG; hopper level switches and material flow switches.

REC 162 *for further details.*

Plessey UK-AN Connectors Brochure

The Plessey Co. Ltd. has made available a revised and enlarged brochure, Publication No. 109/1, giving comprehensive details of the aluminium range and the steel range of UK-AN connectors.

In addition to full technical and physical details, information is included on wiring procedures and the necessary tools. Supplementary information covers the design and electrical features of these connectors together with the use of hermetically-sealed (glass-sealed) connectors.

REC 163 *for further details.*

"Microseal" Components

Advances in a Recent Microminiature Components Packaging Technique

MICROMINIATURIZATION, in the opinion of Hughes International (U.K.) Ltd., may change the shape and form of electronic devices—but not the economics that govern their design and use. Economical assembly and maintenance will remain the paramount design objectives and only in a few isolated cases will it be possible to justify throw-away circuit modules containing dozens or hundreds of components. Whatever packaging technique is adapted, therefore, it must be possible to test and replace components on an individual basis.

Microseal diodes and transistors, developed by Hughes International, are said to provide the first *practical* solution to this microminiaturization problem. The Microseal package permits the design of microcircuit elements with a component density equal to that of any encapsulation or imbedment method using discrete components. Yet each component is readily accessible for inspection or replacement. Moreover, since these components have no leads to manipulate or position, they are suited to automatic circuit-assembly procedures. In the case of the Hughes-developed Swiss-cheese packaging technique, they are handled exactly like eyelets or feedthrough terminals. Small quantities of the components are also available with ribbon leads.

With the distance between components reduced to an absolute minimum the frequency capability of orthodox circuit elements is sharply increased and the new concept may well begin a new era in electronic design and manufacture.

The Microseal package for semiconductor components occupies only a small fraction of the allowable space recommended by those industry groups setting microminiaturization standards. Yet, within this space is a complete transistor or diode structure that is designed to meet every present operating requirement for equivalent commercial units.

The basic configuration is that of a small, rugged ceramic cylinder, 0·062 in. in diameter. The ends are capped with round metal plates to provide a total thickness of 0·030 in. and the metal and ceramic are brazed together to form a hermetically-sealed container. The reliability standards set for the new units are said to be higher than those for established Hughes semiconductor units.

The Microseal package is both a design and manufacturing accomplishment. The semiconductor die is the only active element in a transistor, yet in a standard "can" package, it occupies only 1/3,000th of the total volume. The rest of the space is required for mounting and connecting elements, and to enable the manufacturer to provide a true hermetic seal around the assembly (even the slightest trace of moisture or atmospheric contamination will degrade the semiconductor performance). The technique eliminates only non-contributing space and weight. To provide a hermetic shield in minimum space, the structure combines an impervious ceramic shell with corrosion-proof metal caps, brazed with precious metal. The whole process will eventually be accomplished by non-manual techniques, which should achieve significant savings in costs.

Since the active semiconductor element within the package is essentially unchanged, almost every diode and transistor produced by the company will be available in the Microseal configuration. Only the physical form of a microcircuit is changed—not its electrical values or design. In certain instances, characteristics such as thermal dissipation capabilities are actually improved.

MICROSEAL DIODES

Except for a reduction in size, the semiconductor die in a Microseal diode is said to be identical with that found in an equivalent glass package.

To form the structure, a diode assembly is enclosed within a ceramic cylinder and the unit then sealed with metal and caps. To provide polar discrimination, the diode cathode electrode is gold clad, and the anode coloured silver. In addition, the cathode electrode or manual techniques may be used to orient the diodes before insertion into the circuit.

MICROSEAL TRANSISTORS

The construction of Microseal transistors is more complex than that of diodes, but the same basic package configuration is used. The transistor die is bonded directly to the bottom end plate, while two wire leads connect the emitter and base to two isolated portions of the top surface. To facilitate the orientation of the transistor within a circuit, an egg-shaped design has been established with a 0·070 in. dimension in the longer direction. As in the case of the diode, the collector electrode is gold clad to provide visual identification and is also attracted to a magnet for automatic handling. Combined with the eccentric shape, this polar information removes any chance of error in placing the base, emitter, and collector contacts in the proper location in the circuit.

SWISS-CHEESE CIRCUITS

Microseal semiconductors may be used in a variety of packaging configurations. However, one that has been thoroughly tested, both in the laboratory and as a production technique, is the Swiss-cheese circuit board.

In this method, the components are mounted within the thickness of the circuit board itself. Holes are drilled or etched into the board material, and the components dropped in place. Connections are made to each end exactly as if the component were a feed-through device. Since a 0·030 in. board is normally used, being the same thickness as the component, the circuit pattern on both sides of the board may be extended directly over the ends of the component, making the semiconductor a part of the printed circuit itself. Passive circuit elements may be either deposited on top of the board surface as thin-film members, or inserted within the board in the same manner as the active elements.

As standardized at Hughes, the Microseal components are laid out on a standard 0·100 in. square modulus pattern. Interconnecting printed-circuit strips run horizontally on one side of the board, and vertically on the other. The strips are 0·030 in. wide, and are separated by 0·020 in.

The circuit pattern may be printed on the board either before the components are inserted or concurrently with the component connections, and with the same material. Experience indicates that either ultrasonic welding or silk-screened conductive adhesives, fired at moderate temperatures, are satisfactory. Welding or conventional soldering is not convenient on parts of this size.

The Swiss-cheese boards feature a number of advantages over potted or encapsulated assemblies. Each component is readily available for test or replacement at virtually no sacrifice in component density. This means significant savings in both the initial assembly and test, and in the maintenance of the circuitry in the field. Moreover, power dissipation problems remain as one of the severest limitations on microelectronic density, and the Swiss-cheese boards can be arranged to provide optimum heat transfer to the surrounding medium, either by convection or radiation. The technique lends itself to micro-systems that are rugged, easy to assemble and maintain and require a minimum of interconnections.

★ ★ ★

Life Testing of an Electro-optical Relay

AN electro-optical relay, under continuous life testing in an actual operating environment since it was revealed by the American Raytheon Company one year ago, has recently exceeded 2 billion operations. At the end of August, 1961, the device was still operating in its test circuit at the rate of more than 5 million operations a day and the anticipated life span of the relay has not yet been approximated.

Four of the Model CK1101 Raysistors devices designed for chopper and relay applications, were placed on life test on 1st July, 1960. Thorough duplication of actual operating conditions were established electrically and environmentally. The resistance was adjusted to allow 2 mA r.m.s. current in each cell, with the degree and rate of reduction in the cell current established as a measure of the approach to the end of life, and there have not yet been any significant changes reported.

The Raysistor includes a light source in the control end, which, when excited actuates a photo-conductor in the signal end, allowing either a.c. or d.c. information to pass. In the life test, the lamps are operated by pulsating d.c. so that any degradation due to polarizing effects will be obtained. To produce a 2 mA r.m.s. cell current, a high peak lamp and cell current is maintained.

The test also uses a 60 c/s half-wave lamp excitation, providing a dark period well in excess of 16 ms. This gives the photocell resistance sufficient time to rise high enough to impose a major portion of the peak line voltage across the cell instead of across the limiting resistor in the circuit.

Operating conditions were made even more realistic by placing the test panel on a window sill where it could receive full solar radiation by day plus any adverse effect from an adjacent steam radiator. Also, the line voltage was not stabilized in any way, maintaining typical conditions under which most equipment is operated. The tests will be continued until an appreciable acceleration in the drop of the current output indicates the approaching end of life.

ACTIVITIES in the Industry

Aero Electronics Ltd.

Aero Electronics Ltd., Horley, Surrey, have been appointed the sole United Kingdom distributor for the United Transformer Corporation, New York.

U.T.C. produce a wide range of transformers, electric wave filters, high-Q coils, reactors and magnetic amplifiers which are designed, in the main, to U.S.A. MIL specifications. Custom built units can be produced in all ranges.

Evershed Motor Division—New Address

To meet the increasing volume of orders and permit further expansion of their fractional horse power motor business, a new Division of Evershed and Vignoles Ltd. has been established at Devonshire Works, Dukes Avenue, Chiswick.

The Chief Applications Engineer, Mr. E. H. Werninck, who deals with home and export sales, has also moved to the new premises. It is anticipated that this move should shortly lead to quicker deliveries and will enable the already wide range of Evershed servo motors, motor generators and associated equipment to be even further enlarged.

JFD Licenses LCC

Mr Jack Goodman, Vice President of JFD Electronics Corporation, Brooklyn, New York, announced the signing of a sales and license agreement between JFD's Components Division and Le Condensateur Ceramigque (LCC), a subsidiary of the CSF group which is one of the most important in the French Electronics Industry.

The agreement covers the representation by the LCC sales and engineering network of the complete trimmer capacitor, fixed and variable inductor lines manufactured by JFD in the six countries of the European Common Market. It also covers the manufacture under license of these lines by LCC. Le Condensateur Ceramique is a leading French manufacturer of fixed capacitors, specializing in the manufacture of ceramic and tantalvtic capacitors for the professional market.

Mr. David Taub, Distributor Sales Supervisor of JFD's Components Division, has just returned from a European trip in which he established liaison and procedures with the executives responsible for the European sales of LCC products.

Dr. E. Eastwood, Ph.D., M.Sc., M.I.E.E., Director of Research at the Marconi Research and Development Laboratories at Great Baddow is seen receiving the Wakefield Gold Medal of the Royal Aeronautical Society. The presentation was made by the President of the Society, Air Marshal Sir Owen Jones, on the occasion of the Wilbur Wright Memorial Lecture on September 12th.

The medal is awarded for contributions towards safety in aviation and recognizes Dr. Eastwood's work in radar, navigational aids and air traffic control.

New Electronics Company for Nigeria

It has been announced by the L. M. Ericsson Company of Sweden and Marconi's Wireless Telegraph Co. Ltd. of England that they have formed a new Company in Nigeria, to be known as the Nigerian Telecommunications Corporation.

An official inauguration ceremony took place at the Federal Palace Hotel, Lagos. Mr. B. C. Thisell, Sales Manager of L. M. Ericsson (representing his Managing Director, Mr. S. T. Aberg), Mr. C. E. Linné, Manager of IPTC (W.A.) Ltd., the L. M. Ericsson agents in Nigeria, Mr. F. S. Mockford (representing Mr. F. N. Sutherland, Managing Director of Marconi's) and Mr. A. W. Cole, Manager of Marconi's Communications Division were among those present.

The purpose of the new Corporation is threefold; to provide an "on-the-spot" organization which can deal rapidly and efficiently with all aspects of telecommunication requirements; to promote the expansion of technical education in Nigeria, and to introduce local assembly of some types of telecommunication units rather than import them already assembled.

The L. M. Ericsson Company is well known all over the world for the quality of its telephone equipment, notably the crossbar telephone exchange, the transistorized carrier systems and the "Ericofon" telephone instrument. They undertake the planning, installation and maintenance of all categories of telecommunication equipment, including nation-wide systems. Since 1960 L. M. Ericsson has been represented in Nigeria by the Industrial Products Co. (West Africa) Ltd. (IPTC).

The Marconi Company is at present responsible for the maintenance of much of the Nigerian Federation telecommunications network. In 1956, under contract from the Department of Posts & Telegraphs, the Company set up a Telecommunication School at Oshodi, Lagos, in which 217 students are currently under training on four-year courses. The initial (1956) intake of trainees have now completed their course and have taken over as maintenance engineers in the Nigerian P. & T. Other Nigerian engineers are undergoing training at the Marconi Works in England.

It is hoped that the formation of the Nigerian Telecommunications Corporation will do much towards increasing the tempo of technical training in Nigeria. Initially it will have its headquarters at the office and factory premises already established by Marconi's on the Apapa Industrial Estate, Lagos.

Centralab to make Plessey Potentiometers

The Plessey Co. Ltd. has granted an exclusive licence to the Centralab Division of Globe Union Incorporated of U.S.A. to manufacture, sell and use in the U.S.A. moulded-track potentiometers made to Plessey designs.

In addition to the exclusive facilities in the U.S.A. the Centralab Corporation has also been granted a non-exclusive licence to make, use and sell these potentiometers in Canada, and Central and South America. Initial period of the agreements is 10 years.

The Plessey Co. Ltd. is the only manufacturer in the United Kingdom producing a range of moulded-track potentiometers. This track consists of a phenolic moulding loaded with carefully controlled portions of conducting carbon filler, and its special features are long life and low electrical noise factor.

Elcontrol Products in the U.S.A.

Elcontrol have announced the conclusion between their Company and The Siegler Corporation Magnetic Amplifiers Division, of New York, an Agreement for the exclusive sale and manufacture of their products in the United States and Canada.

The Siegler Corporation have extensive sales coverage in the United States, and many manufacturing plants, with a turnover of approaching $100,000,000 per year.

The President of the Magnetic Amplifiers Division, Mr. Herbert Herz, has recently paid a visit to this country in order to conclude arrangements.

Avo Mobile Demonstration Unit

The Avo Mobile Demonstration Unit has recently completed a tour of Western Germany, where it visited a number of establishments. A comprehensive range of electrical, electronic and nucleonic instruments were demonstrated and technical staff were available to answer queries.

A representative selection of the products manufactured by International Rectifier Co. Ltd., (another member of the Metal Industries group of companies) was on show, including a transistor radio which, instead of being operated by batteries, was powered by solar cells.

Aerials for Guided Missile Training

Cossor Radar & Electronics Ltd., is supplying five aerials and associated synchronization equipment for use by the War Office at the Trials Establishment, Guided Weapons, Royal Artillery, on the coast of Anglesey.

The Cossor equipment consists of five helical aerials, together with equipment for slaving these to the bearing and elevation read-out from a master tracking equipment. Two of the five aerials are for use with dual purpose transmitters in the 100 Mc/s region. Of these, one is kept in a "stand-by" condition. Signals transmitted from the other aerial interrogate equipment carried by the airborne missiles, and the reply signal is received in the 200 Mc/s region by a third aerial. The remaining two aerials operate in the 400 Mc/s region, and receive other telemetered information from missiles in flight.

The unusual helical aerial is circularly polarized—an important factor in this application, for some missiles spin whilst in flight. Only by using circular polarization can unwanted signal modulation be minimized. Use of the helical aerial also results in a more mechanically rigid structure, than would be possible with alternative types of aerial, at these frequencies.

Mullard Equipment Ltd.—New Telephone Number

The telephone number of Mullard Equipment Ltd., Crawley New Town, Sussex, was changed to Crawley 28787 as from 23rd October last.

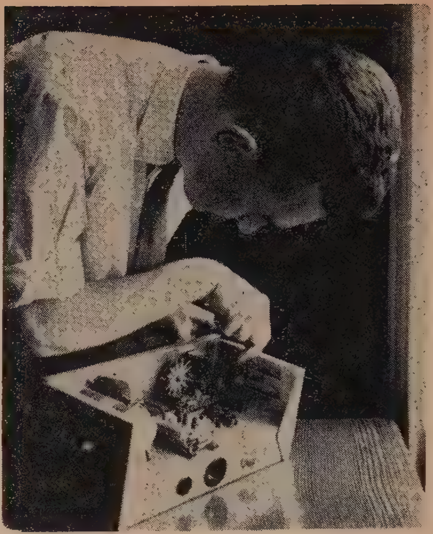
C.E.C. Inc. form British Company

"We have set up our British Company for two reasons in particular", said Mr. Philip Fogg, Chairman of the Consolidated Electrodynamics Corporation, Inc., Pasadena, California, U.S.A., and also Vice-Chairman of the Bell & Howell Company, Chicago, when he visited the new Woking headquarters of the recently formed Consolidated Electrodynamics Corporation (U.K.) Ltd., on Monday, 25th September.

"Firstly, we have had for many years a continually expanding market for our instruments in Britain", he continued.

"Secondly, we have had experience of the ingenuity and skill of British scientists, engineers and craftsmen and we want to take advantage of these talents to develop further our world markets.

The headquarters of the new Consolidated Electrodynamics Corporation (U.K.) Ltd., is at 14 Commercial Road, Woking, Surrey. The telephone number is Woking 5633 and the Telex No. 8-582.



Mr. M. Bond, a radio amateur of Chislehurst in Kent, whose call sign is G3NWF, has been using what is believed to be one of the first transistorized transmitters to work in the 7 Mc/s band, giving an output of 10 W. He has made contact with a number of other amateurs in England and Wales and he has talked to Norway, Denmark, Germany, Finland and Bulgaria.

The transmitter is fully transistorized, using two STC TK202A h.f. silicon power transistors in push pull for the output stage and another TK202A as the driver. The crystal-controlled oscillator uses a TK252A transistor–a low power version of the TK202A.

This picture shows Mr. Bond screwing down one of the output transistors.

C.E.C. (U.K.) Ltd., is a wholly-owned subsidiary of Bell & Howell, S.A., Fribourg, Switzerland, which in turn is owned by the Bell & Howell Company, Chicago. C.E.C., Inc., Pasadena, having an annual turnover of $55,000,000, is wholly-owned by the Bell & Howell Company and, itself, owns the Consolidated Electrodynamics Corporation, G.m.b.H., at Frankfurt, Germany.

Arrow Electric Switches—Change of Address

Arrow Electric Switches Ltd. wish to advise their many friends that correspondence is still being sent to Hangar Lane, W.5, instead of to their new correct address, Brent Road, Southall, Middlesex. Tel.: Southall 2442.

A New Address for Simmonds Aerocessories

Simmonds Aerocessories Ltd., of Treforest, Glamorgan, a member of the Firth Cleveland Group, and a leading manufacturer of specialized fasteners—Nyloc and Pinnacle self-locking nuts, Simmonds weld nuts and Spire speed nuts—and a wide range of

Continued on page 884

PERSONALITIES

Mr. R. L. Higgin

Mr. J. W. Warner

Mr. J. White

Mr. R. L. Higgin

The Plessey Co. Ltd. announces the appointment of Mr. R. L. Higgin, A.M.I.E.E. as General Manager, Components Group.

Mr. Higgin joined Plessey in March 1959 as Group Commercial Executive, Components Group.

Mr. G. H. Walton

The retirement is announced of Mr. G. H. Walton, a Director of British Insulated Callender's Construction Co. Ltd. and of Painter Bros. Ltd., both members of the BICC Group. He had served with the Group and its predecessors for more than 47 years.

Mr. Walton, who is also a former director of BIC (Submarine Cables) Ltd. and of Engineering Projects Ltd., relinquished his executive duties as Joint General Manager of the BIC Construction Co. Ltd. in 1958, but continued to occupy a seat on the Board and to undertake special assignments.

After five years' training at the Birkenhead Works of Cammell Laird & Co. (Shipbuilders and Engineers) Ltd., Mr. Walton joined the former British Insulated Company in 1914 as a contract engineer. He served throughout the First World War in the London Electrical Engineers and the Royal Air Force, rejoining the BI Company in 1919. For three years he served as an assistant contract engineer in the north-east coast area becoming resident engineer-in-charge, Middlesbrough Area, in 1922. His duties around this time took him to New Zealand, Australia, China and the United States.

In 1927, Mr. Walton was appointed Contract Manager of the Company, a position he retained until 1940 when he became Manager of the Helsby factory. In 1948 he was appointed Director and General Manager of the Radio Gramophone Development Co. Ltd., formerly owned by the BICC Group, going on to become Executive Director of BIC Construction Co. Ltd. in 1952. In 1956 he was appointed Director and Joint General Manager of the Company.

Mr. J. W. Warner

Mr. J. W. Warner, M.A. has been appointed to the Board of Alkaline Batteries Ltd., manufacturers of Nife and Britannia batteries.

Educated at Malvern and Clare College, Cambridge, Mr. Warner graduated in 1923 with Honours in Mechanical Engineering, after which he received practical training with J. I. Thornycroft & Co. Ltd. of Basingstoke, before joining the Anglo-Persian Oil Co. (now B.P. Ltd.) as Refinery Development Engineer.

In 1931 he joined The Chloride Electrical Storage Co. Ltd. and was appointed General Manager for India.

Mr. Warner was appointed General Manager of Alkaline Batteries Ltd. in 1946. He is a member of the Institute of Mechanical Engineers and an Associate Member of the Institute of Electrical Engineers.

Sales Appointments at Polypenco

Polypenco Ltd., manufacturers of engineering industrial plastics, announce the appointment of two additional Sales Engineers to expand their team operating throughout Great Britain.

Mr. Jack Brunwin will be servicing customers and potential users of industrial plastics in the Southern Counties. Mr. Brunwin has had many years experience in electrical engineering and associated products including p.t.f.e.

In the East and West Midlands territories, the services of **Mr. John Palmer** have been acquired. Mr. Palmer has already been associated with industrial plastics in the forms of adhesives and films, and is well known in Midlands industry.

Mr. J. N. Wilkinson

Telefusion Ltd. announce that Mr. John Nairn Wilkinson, B.A.(Comm.) has been appointed a Joint Managing Director, together with Mr. John Cyril Wilkinson Chairman and Managing Director.

Mr. J. White

Mr. Jack White, formerly with Mullard Ltd. on the Commercial Section of their Semiconductor Division, has now moved to Texas Instruments Ltd., Bedford, as Sales Administration Manager.

Mr. P. Bonner

The George Cohen 600 Group Ltd. has appointed Mr. Peter Bonner, B.Sc., A.M.I. Mech.E., A.M.I.Prod.E., to the Board of its Associate Company, T. C. Jones & Co. Ltd., Structural Engineers of London and Treorchy, South Wales.

Immediately prior to joining T. C. Jones & Co. Ltd., Mr. Bonner was with Ashmore, Benson, Pease & Co. Ltd., members of the Davy-Ashmore Group, where he held technical sales, production engineering and managerial positions. He served his engineering apprenticeship with Dorman Long & Co. Ltd., later reading Engineering at Durham University.

Mr. B. L. Muller

Mr. Bernard L. Muller, Sales Director of Regentone Radio and Television Ltd., has been appointed Sales Director of Regentone Products Ltd. and directs sales for Regentone, R.G.D. and also the third company in the group, Argosy. Mr. H. O. Thomas, who was in charge of sales of Radio Gramophone Development Co. Ltd., has resigned.

Mr. Muller's career in the industry began with Marconiphone in 1936. After a spell at Cossor he moved to Sobell as Administrative Assistant to the Managing Director and became Sales Manager in 1948.

Five years ago he joined Regentone as Sales Manager. In 1958 he was appointed Sales Director, and the following year he became, in addition, Sales Director of another company in the group, Argosy.

Mr. Muller will operate from the new West End Sales office, Brook House, Davies Street, W.1.

Mr. E. G. Taylor

Following an announcement by Mr. R. H. Phillips, Managing Director of G.E.C. Installation Equipment Group, that a new distribution system is being established to help service to wholesalers and contractors, it has been revealed that Mr. E. G. Taylor, M.I.E.E., F.I.E.S., will henceforth be assigned to a special duty of "wholesale liaison" in the north of England.

Although he will be attached to Group Headquarters, Mr. Taylor will operate from Manchester. Formerly manager of G.E.C.'s north-west area, he has been with the Company for forty-eight years and has worked in the north-west since 1930.

Mr. Taylor, who is married, is a graduate of Birmingham University. He began his career with G.E.C. as an apprentice at Witton Engineering Works, followed later by a year in the Estimating and Contracts Department. From 1922 to 1924 he was technical assistant at the Company's Liverpool office, then branch engineer at Swansea for six years.

He moved to Liverpool, as branch engineer, in 1930, and became branch engineer to Manchester additionally, in 1939. At the end of the war he was appointed manager, industrial sales, at Manchester branch, and in 1954 became assistant district manager for the north-west area. Mr. Taylor was appointed manager of the area in 1958.

In 1941-42 Mr. Taylor was chairman of the Mersey and North Wales Centre of the Institution of Electrical Engineers, and he served on the Council of the Institution from 1941 to 1944. He was a member of the Anglo-American Materials Handling Productivity Team in 1949. Since 1957, he has been local Honorary Treasurer of the Benevolent Fund of the I.E.E., North Western Centre.

Mr. A. T. Black

K.M.G. Electronics Ltd., Richmond, Surrey have appointed Mr. A. T. Black, C.B.E., A.Inst.C.E., M.I.Mech.E., as Managing Director since 1st October, 1961. He is, however, still carrying on his interests as a consultant.

Mr. Black is well known to Industry, and was for many years a member of the Directorate of the Ministry of Supply.

Mr. Black has been specially appointed to lead the new and very progressive programme which K.G.M. is now putting into effect.

Mr. S. Bellis

British Insulated Callender's Cables Ltd. announce, with regret, the death on 17th September of Mr. Samuel Bellis, Sales Manager (Central Marketing) of BICC. He was aged 63 and died in hospital at Cobham, Surrey.

Mr. Bellis joined Messrs W. T. Glover & Co. Ltd., of Trafford Park, Manchester—a member of the BICC Group—before the First World War, in which he served in the infantry and the Royal Flying Corps. In June 1919 he joined the former British Insulated and Helsby Cables Ltd. at Manchester in the Estimating Department, where he later became a sales representative.

In 1930, Mr. Bellis was appointed Manager of the Blackburn Branch and in July 1945, following the formation of BICC through the amalgamation of British Insulated Cables and Callender's Cable & Construction Co., he became manager of the Leeds Branch of the new company. Five years later Mr. Bellis was transferred to London as Assistant Home Sales Manager and in December 1952 came his appointment as Sales Manager London, after which in February 1957 he became Sales Manager (Central Marketing).

Garrard Engineering Board of Directors

Following the recent announcement that The Garrard Engineering and Manufacturing Co. Ltd. of Swindon had become a wholly owned subsidiary of The Plessey Co. Ltd., the formation of a reconstituted Board of Directors is announced by Plessey. New Directors of the Company are: **Mr. A. E. Underwood** (Chairman); **Mr. Hector V. Slade** (Managing Director); **Mr. K. J. Slade, Mr. J. Tyldesley, Mr. John A. Clark, Mr. Michael W. Clark.**

Plessey also announces that **Sir William Stanier** has resigned from the Garrard Board, and has been offered an appointment as a Director of Machine Products Ltd. which he has accepted. **Mr. Donald F. Brown** has also resigned from the Garrard Board and has joined the Board of Hawley Products Ltd. Both Machine Products Ltd. and Hawley Products Ltd. are members of the Plessey Group of Companies.

A. C. Cossor Ltd.

As a result of the purchase of A. C. Cossor Ltd. by Raytheon Company of Massachusetts, U.S.A., the following gentlemen have been elected to the Board of A. C. Cossor Ltd.: **Mr. Charles Francis Adams,** Chairman of the Board of Raytheon Company. **Mr. Richard E. Krafve,** President of Raytheon Company. **Dr. Carlo L. Calosi,** Vice-President of Raytheon Company.

Raytheon have already announced their intention of preserving the identity of the Cossor Group. Major-General Sir Miles Graham continues as Chairman, and Mr. James S. Clark as Managing Director.

ACTIVITIES IN THE INDUSTRY

Continued from page 882

standard and cold formed nuts, have now moved their Birmingham Midland Area Sales Office.

This move, from Lancaster House, Newall Street, to new and larger office accommodation at Herbert House, Cornwall Street, caters for continuing expansion and increased staffing requirements. The existing Telex numbers 33-312 and Birmingham Central 2248-9 telephone numbers have been retained and a third telephone line, Birmingham Central 2719, has been added.

Simmonds products for the Midland Area are marketed under the direction of Mr. A. H. Patterson, Midland Area Manager for the Nut and Bolt Sales Division, and Mr. K. E. Amos, Assistant Sales Manager for the Spire Speed Nut Division.

New Premises for Brimar

The Brimar Commercial Office, Stores, Service and Shipping Departments, have moved to the Company's new location at Rochester. The new, specially designed layout of these premises will enable Brimar to provide a much improved service to customers.

All orders by post and enquiries other than those concerned with export and publicity (the Departments dealing with these two matters are staying at Footscray until further notice) should be sent to the following address: Brimar Commercial Division, Thorn-A.E.I. Radio Valves & Tubes Ltd., Rochester, Kent.

Telephone enquiries from the London dialling area can still be made to FOOtscray 3333, Ext. 424, but long distance calls should be made direct to Rochester: Tel.: Chatham 44411.

New Name for Racal

The broadening field of their activities in recent months has prompted Racal Engineering Ltd. to change their name to Racal Electronics Ltd. with effect from 1st October last.

Racal Engineering was formed in 1951—the name compounded from the names of the two founders—RAymond Brown and CALder Cunningham. Since then, the reputation of the Company in the field of radio communications has grown so that it is known by users of communication equipment all over the world.

Amprobe Instrument Corporation

The Pyramid Instrument Corporation of New York, manufacturers of portable electrical test equipment, has recently changed its name to Amprobe Instrument Corporation.

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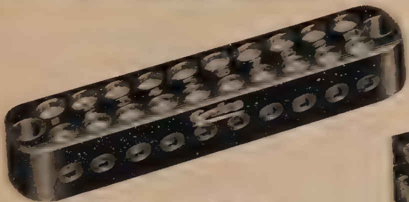

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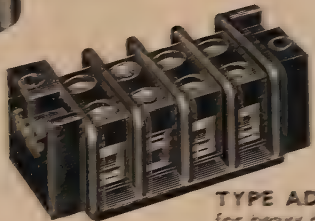

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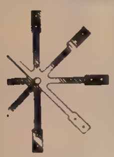

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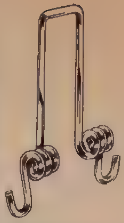
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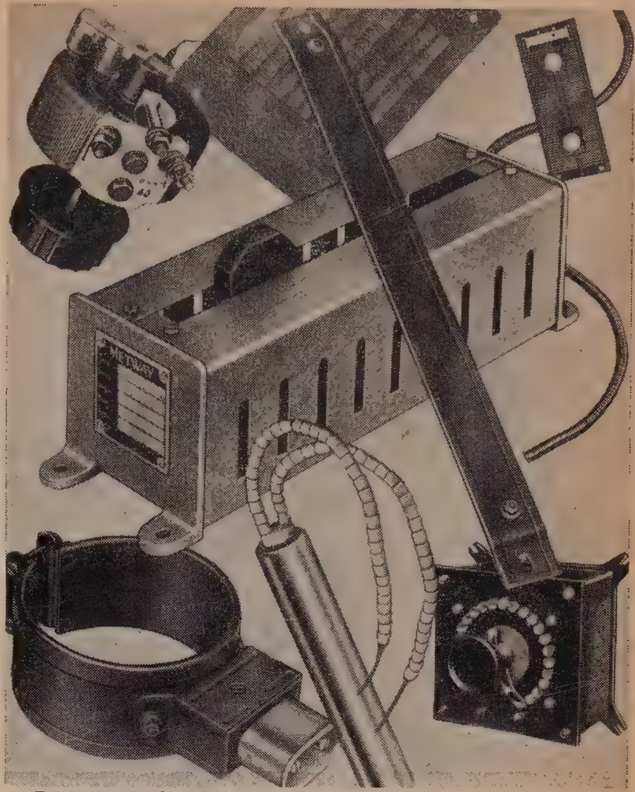

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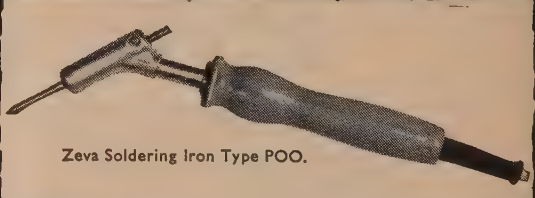

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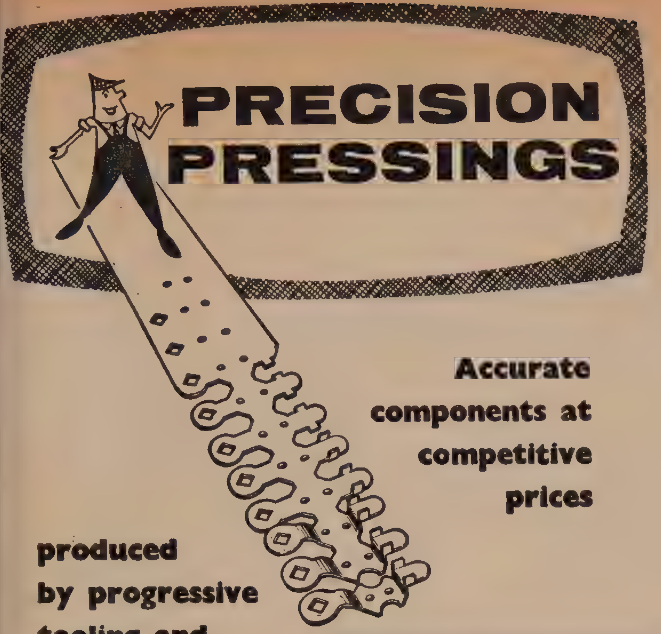

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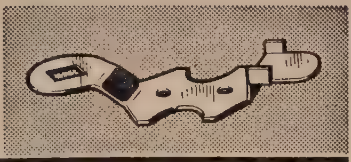

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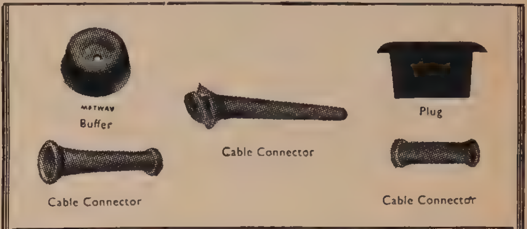

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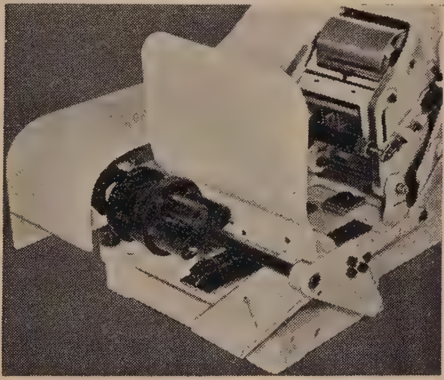

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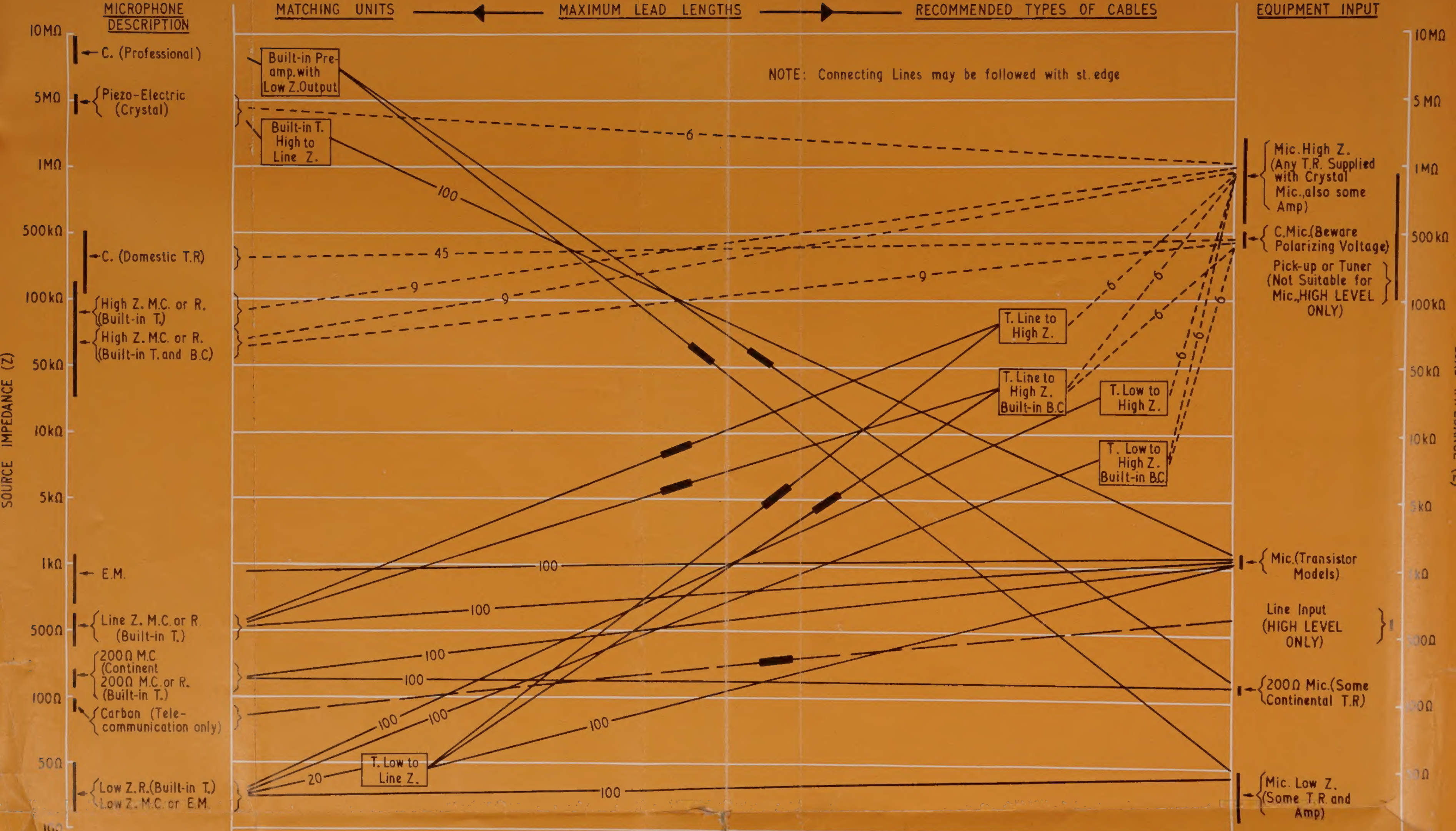
Microphone to Equipment Matching Chart

Reprinted from:—
Radio & Electronic Components
Vol. 2. No. 5. May, 1961

MICROPHONE TO EQUIPMENT MATCHING CHART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1MΩ
500kΩ
100kΩ
50kΩ
10kΩ
5kΩ
1kΩ
500Ω
100Ω
50Ω
10Ω
C. (Professional)
Piezo-Electric (Crystal)
C. (Domestic T.R)
High Z. M.C. or R. (Built-in T.)
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200Ω M.C. or R. (Built-in T.)
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NOTE: Connecting Lines may be followed with st. edge
T. Line to High Z.
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6
45
9
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100
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20
6
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6
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C. Mic.(Beware Polarizing Voltage)
Pick-up or Tuner (Not Suitable for Mic., HIGH LEVEL ONLY)
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Mic. Low Z. (Some T.R. and Amp)

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——	=	Twin Screened Cable
- - - -	=	Co-axial Cable
—▬—	=	Max. Length. Several Miles
—100—	=	Recommended Max. Length (ft.)
Ω	=	Ohms
kΩ	=	Ohms × 1,000
MΩ	=	Ohms × 1,000,000
Z	=	Impedance
C	=	Condenser
B.C.	=	Blocking C.
T.R.	=	Tape Recorder
Amp.	=	Amplifier
Mic.	=	Microphone
M.C.	=	Moving Coil
R	=	Ribbon
E.M.	=	Electro-Magnetic
T	=	Transformer

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